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THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

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This Month's Cover: Double-head stitcher, built by Acme Steel Co., is a high-production machine for operations which require two stitches. Narrow heads are mounted on an 8-inch rail, allowing spacing from 1¾ to 6 inches.

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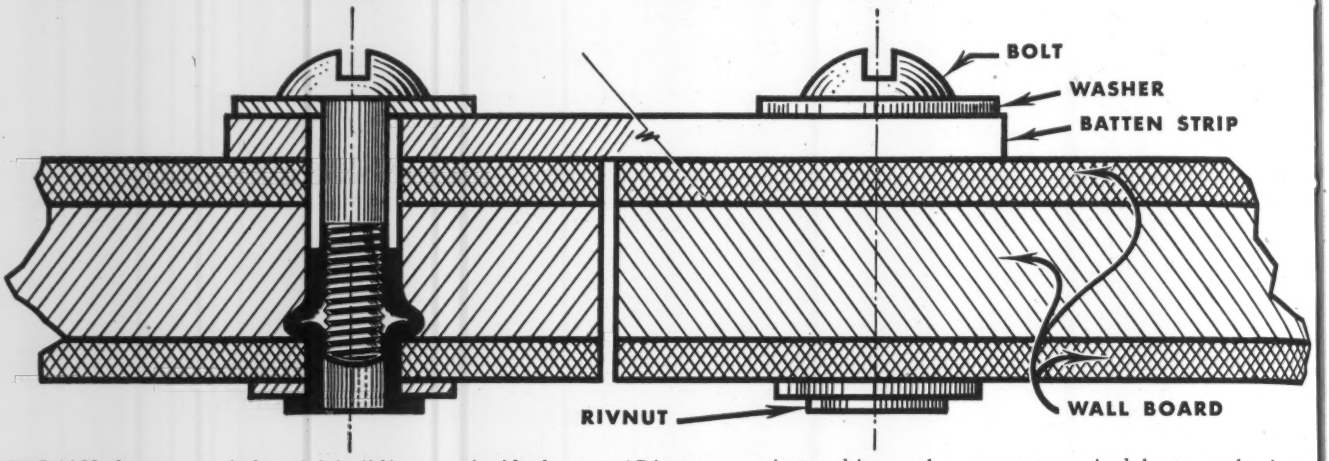
NEW ¼" STEEL RIVNUT

improves building design . . . speeds construction . . . cuts costs



PLANS for a new industrial building called for low-cost, quick construction and good appearance. One-inch asbestos cement-clad insulation siding—in 4′ x 10′ sheets—solved material needs, but the size of the sheet made it a blind fastening job—and a tough one!

Because it is both blind rivet and nut plate, the new ¼″ steel Rivnut provided the ideal answer! Rivnuts were inserted in jig-drilled wall holes and upset with power heading tool by one man, working from one side. Batten strips were placed where siding sheets met and securely fastened with bolts, threaded into Rivnuts (threads stay clean after upset).

Rivnuts greatly reduced man-hours and material costs on this job. They improved the appearance. And because they're so simple to use, not a single fastening operation was ruined—even though the men were inexperienced with Rivnuts and the heading tool!

If you have a fastening problem, why not call in a Rivnut engineer? Write to The B. F. Goodrich Company, Dept. MD-118, Akron, Ohio.

Now! Rivnuts and Rivnut heading tools for every fastening need

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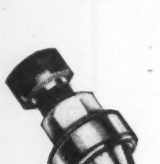
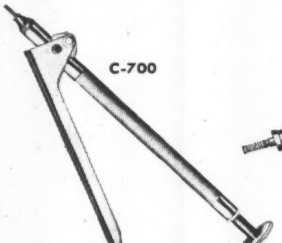
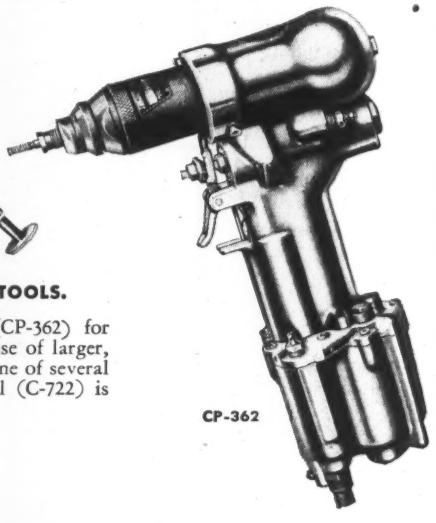
Standard Rivnuts are available in sizes ranging from 4-40 to new $\frac{5}{16}$″ size. In flat, brazier, countersunk and washer heads. Brass, aluminum, and steel. New types and sizes specially engineered.





2. POWER AND MANUAL HEADING TOOLS.

New pneumatic-hydraulic heading tool (CP-362) for production line fastening. Makes possible use of larger, stronger Rivnuts. Speed Header (C-700) is one of several manual types available. New heading tool (C-722) is repair-depot type for small requirements.



3. HOW AND WHERE TO USE RIVNUTS.

New edition, just off the press! Gives applications, step-by-step installation. Lists types, sizes, grip ranges. Discusses heading tools. Includes test data. Fully illustrated. For your free copy, write to The B. F. Goodrich Co., Dept. MD-118, Akron, Ohio.

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RIVNUTS

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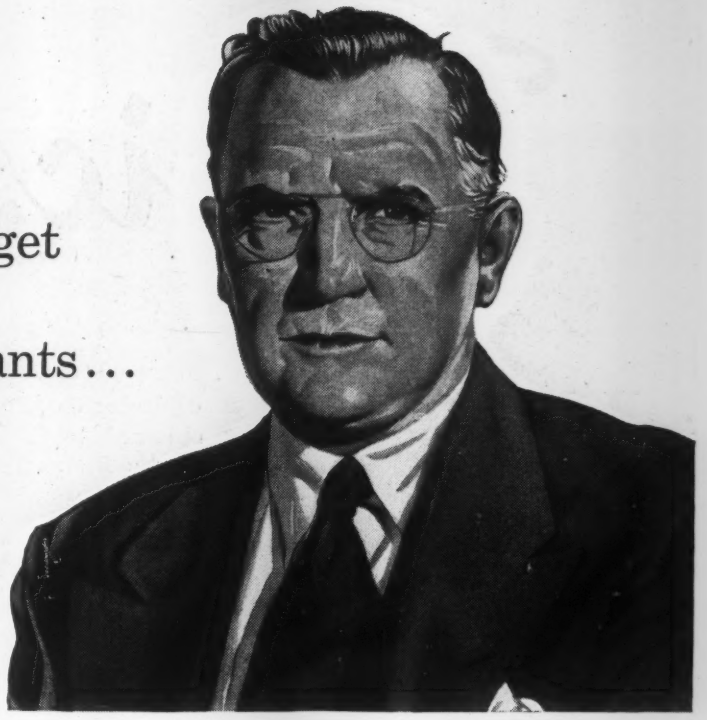

HE: ***Every woman knows aluminum kitchenware! Millions will want my nursery equipment . . .***

WE: ***That's why saying NO is so tough . . .***

There is no mystery in the reasons.

We have talked aluminum, aluminum, aluminum, for sixty years.

Manufacturers, and Americans in general, during the war, learned what aluminum could do. As it fought America's battles in the sky, they saw it win other battles against great stresses, against corrosion, against old-fashioned manufacturing methods. Hundreds of thousands of skilled American hands learned to work with aluminum . . .

All of these facts, put together, caused a kind of postwar revolution. A manufacturer of nursery equipment, or farm roofing, or appliances, or irrigation systems, redesigned his line to take advantage of aluminum's usefulness. *Suddenly, thousands of such manufacturers were clamoring for aluminum!*

So many that—with aluminum as with countless other products—the world demand exceeded the supply. And America's new aircraft program subtracts its large and necessary share.

That is why, right at this enthusiastic moment, events force us to learn to say NO. We must say a flat NO to those who want aluminum because they can't get their regular metal. A milder NO to new aluminum users with ideas that are economically sound. We will endeavor to supply them with the small amounts needed for experimental use. Very drastic NO's to many of our own fabricating plants, which, for some time, we have operated at only a fraction of their capacity.

Every time we have to say NO to a customer, it will be the fairest NO we know. Our first obligation is, of course, to the host of old customers who have put all their eggs in the aluminum basket.

But there will be no light decisions. Your Alcoa salesman and his District Manager will work out the answers, as a team whose guiding motive is this:

We want more and more of your business, as soon as we can make more aluminum available.

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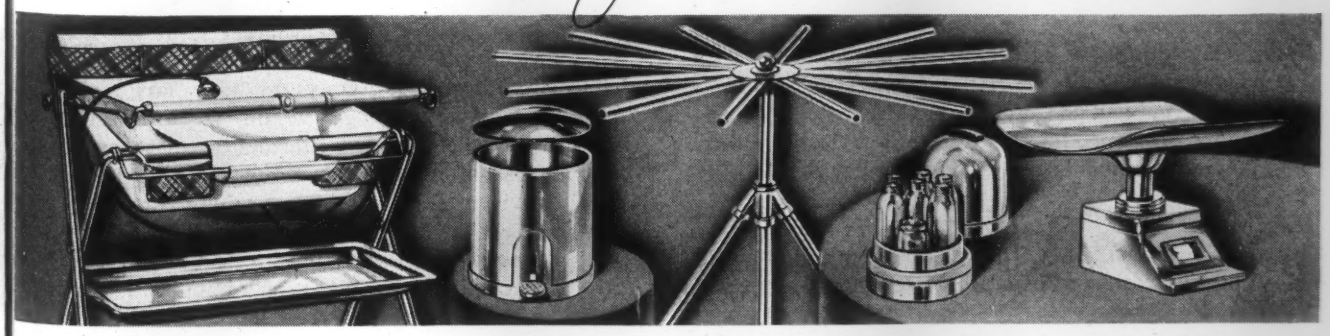


Topics

LOW TEMPERATURES within 0.001-degree of absolute zero have been obtained by using paramagnetic salt and a magnetic field. First the salt is placed in the field of an electromagnet where it gives up a large amount of its energy. When the field is removed the rapid absorption of heat by the salt produces this phenomenally low temperature.

BUYERS' MARKET in the lower priced automobile field is not expected to arrive for another year and a half, according to the Ford Motor Co. Backlog of cars and trucks for the company will still total about two million at the start of 1949.

NEW COOLANT for use in grinding and machining operations on metals and plastics has been formulated by Arnold, Hoffman & Co. Known as Ahcowet CG, it is a clear, water-soluble emulsion which penetrates the porosity of grinding wheels and cutters, resulting in longer tool life and cooler operation. Coolant is odorless, nonirritating and rust inhibiting.

TAGGED ATOMS, radioactive tracers, are added to solutions in which tire cords are treated. Radiographs indicate penetration of the solution into the cord showing characteristics of the solution on various types and grades of cords.

SCALE MODELS of its fork-lift trucks, tractors and accessories are being offered by Towmotor Corp. to assist its customers in factory layout problems. The increased use of scale model buildings, machinery and equipment for visual planning indicate that other manufacturers may also supply models of their machines for production or materials handling. Towmotor models are ¼-inch scale.

INDUSTRIAL COATINGS formulated with Vinylite resins afford protection from corrosive action of sea water, and resistance to abrasion. The new coatings have been used on offshore petroleum drilling equipment in the Gulf of Mexico, prolonging life and reducing maintenance of equipment.

JET ENGINES are housed in the same nacelles as the reciprocating engines in the Navy's latest land-based patrol plane, the P4M-1 Mercator. Two 4000-pound thrust jets assist the two 3250-hp Wasp Major engines for quick bursts of speed. Cruising range for the 40-ton craft is 3000 miles.

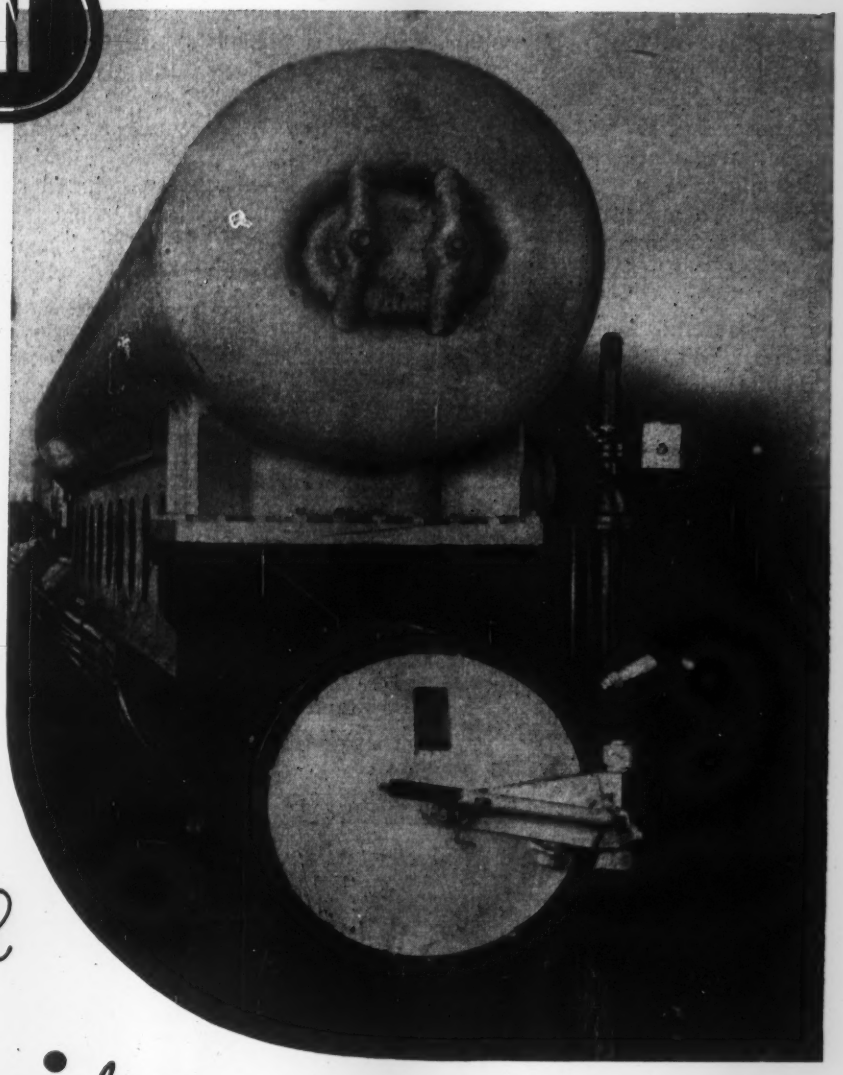
STORAGE BATTERIES of the nickel-cadmium type, well-known in Europe but relatively unheard of in this country, are free from many of the limitations of the common lead-acid type. Life is about 20 years, steel case does not break, battery retains charge during idle periods, cannot freeze, and requires relatively little maintenance. Manufacturers are making plans to produce these batteries in this country.

PNEUMATIC TIRES on idlers carrying conveyor belts will cushion the shock of loading materials, particularly if the materials are heavy and have sharp or jagged edges. A Goodyear patent, the system has successfully protected conveyor belts against the shock of 300 pound boulders falling 12 feet, an impact of 43,000 inch-pounds.

VAPORIZING METAL samples in a small filament type furnace has enabled William M. Hickam, Westinghouse physicist, to trace metal impurities by means of a mass-spectrometer. With a two-milligram sample the method will detect as little as one part of impurity per million.

In this section of the September issue the use of etched chromium plating for antifriction bearings was discussed. Only on very large and heavily loaded bearings would the races be screen etched to retain lubricants. Otherwise the process of microscopic-screen etching is for application on metallic surfaces where they work together under high heats and speeds to prevent seizure or galling due to the inadequate oil-film retention inherent in chromium surfaces.

MACHINE DESIGN



Ball Release Mechanism . . . .

triggers shock-testing air gun

By John H. Armstrong
Naval Ordnance Laboratory
U.S. Naval Gun Factory
Washington, D. C.

FINAL effectiveness of a weapon is often determined by its resistance to shock. Aircraft-dropped mines and torpedoes are effective only because their complicated mechanisms are capable of surviving the high accelerations resulting from impact with the

Fig. 1—Above—Muzzle-end view of air gun showing torpedo-tube type quick-operating muzzle door. Gun is used for shock testing weapon components

water surface. In the guided missile field a major problem is the development of control devices which can resist the accelerations of launching the weapon and, in some cases, function satisfactorily during the shock. Other weapons depend on inertia-operated devices for arming or exploding, and such devices may be called upon to discriminate between applied shock patterns; a bomb fuze, for example, might be designed to function reliably upon impact with hard targets while remaining insensitive to water entry accelerations.

A necessity, therefore, in efficient ordnance development are laboratory machines for applying known shock patterns to weapons and their components. Under these controlled conditions their resistance or response to acceleration can be studied economically, with communication maintained with the tested item during the shock and its undamaged recovery afterward assured. Largest and most versatile of the various types of shock testing machines built at the Naval Ordnance Laboratory is the new 21-inch bore air gun, illustrated in *Fig.* 1.

Shock-testing air guns are used to simulate field shock conditions associated with high velocity impacts, such as on mines launched from aircraft, or with relatively long-duration accelerations as in the launching of missiles, compressed air supplying the large amounts of energy required. Their general scheme of operation is shown in *Fig.* 2, while the actual dimensions and capacities of the 21-inch air gun appear in TABLE I.

Heart of the air gun, and its most difficult design problem, is the release mechanism. It must sustain and release exceedingly heavy loads in some tests and yet be capable of releasing loads 100 times smaller in a consistent, reproducible manner. The so-called "ball release" mechanism, in which a member is freed when spheres engaging a groove are allowed to move outward by withdrawing a surrounding sleeve, has seen extensive use in ordnance and other applications for many years, though generally for relatively small loads. The successful use of this class of mechanism for handling loads up to 175,000 lb in earlier air guns designed at NOL made it a preferred choice for this application, since experience in its operation and foreknowledge of possible difficulties made successful operation of the required 340,000-pound capacity device more likely than if a wholly different scheme were used.

As is indicated in the acceleration-time curve of typical air gun performance in *Fig.* 2, the time required for the piston to become completely free of restraint from the release mechanism after it first starts to move is important in that it represents the rate at which the shock loading is applied to the test load. With the usual type of ball release, this time is dependent on the size and configuration of the parts, the relative weights of the piston and the parts of the release itself which must be accelerated during release, and the air force acting on the piston. In any given test, the rate of release and the peak acceleration reached are interdependent, since both depend on the air pressure used.

Independent control of the release time is secured in the 21-inch gun by use of a two-stage ball release, thus permitting a wider range of shock patterns to be produced as required. The complete mechanism is pictured in cut-away form in *Fig.* 3, and in the

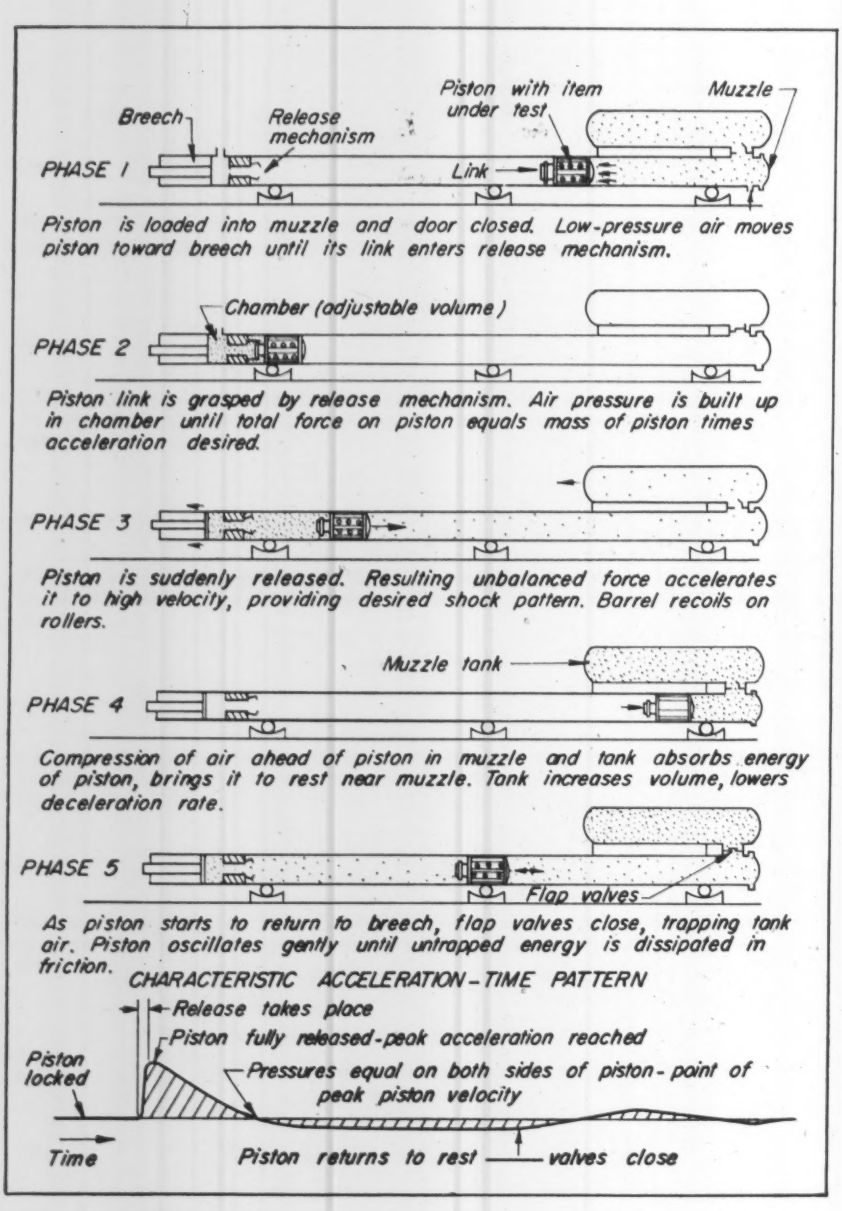

Piston with item under test
Muzzle
Breech
Release mechanism
PHASE 1
Link
Piston is loaded into muzzle and door closed. Low-pressure air moves piston toward breech until its link enters release mechanism.
Chamber (adjustable volume)
PHASE 2
Piston link is grasped by release mechanism. Air pressure is built up in chamber until total force on piston equals mass of piston times acceleration desired.
PHASE 3
Piston is suddenly released. Resulting unbalanced force accelerates it to high velocity, providing desired shock pattern. Barrel recoils on rollers.
Muzzle tank
PHASE 4
Compression of air ahead of piston in muzzle and tank absorbs energy of piston, brings it to rest near muzzle. Tank increases volume, lowers deceleration rate.
PHASE 5
Flap valves
As piston starts to return to breech, flap valves close, trapping tank air. Piston oscillates gently until untrapped energy is dissipated in friction.
CHARACTERISTIC ACCELERATION-TIME PATTERN
Release takes place
Piston fully released-peak acceleration reached
Piston locked
Pressures equal on both sides of piston-point of peak piston velocity
Time
Piston returns to rest
valves close

Fig. 2—Left—Step by step operation of air gun shown schematically

cross section drawing, *Fig.* 4, which show the piston, *A*, locked in place. The piston link, *C*, is released by motion of the release sleeve, *I*. The release sleeve in turn is locked in place by an inner set of balls, *N*, and the power to accelerate it during quick release comes principally from air pressure in the release sleeve chamber, *L*. This pressure may vary independently of that in the main air gun chamber, *U*, which accelerates the piston itself. Release is initiated by means of the central hydraulic cylinder, *S*, which triggers the inner release balls by withdrawing the shuttle, *O*, which is the counterpart of the release sleeve in the piston locking arrangement.

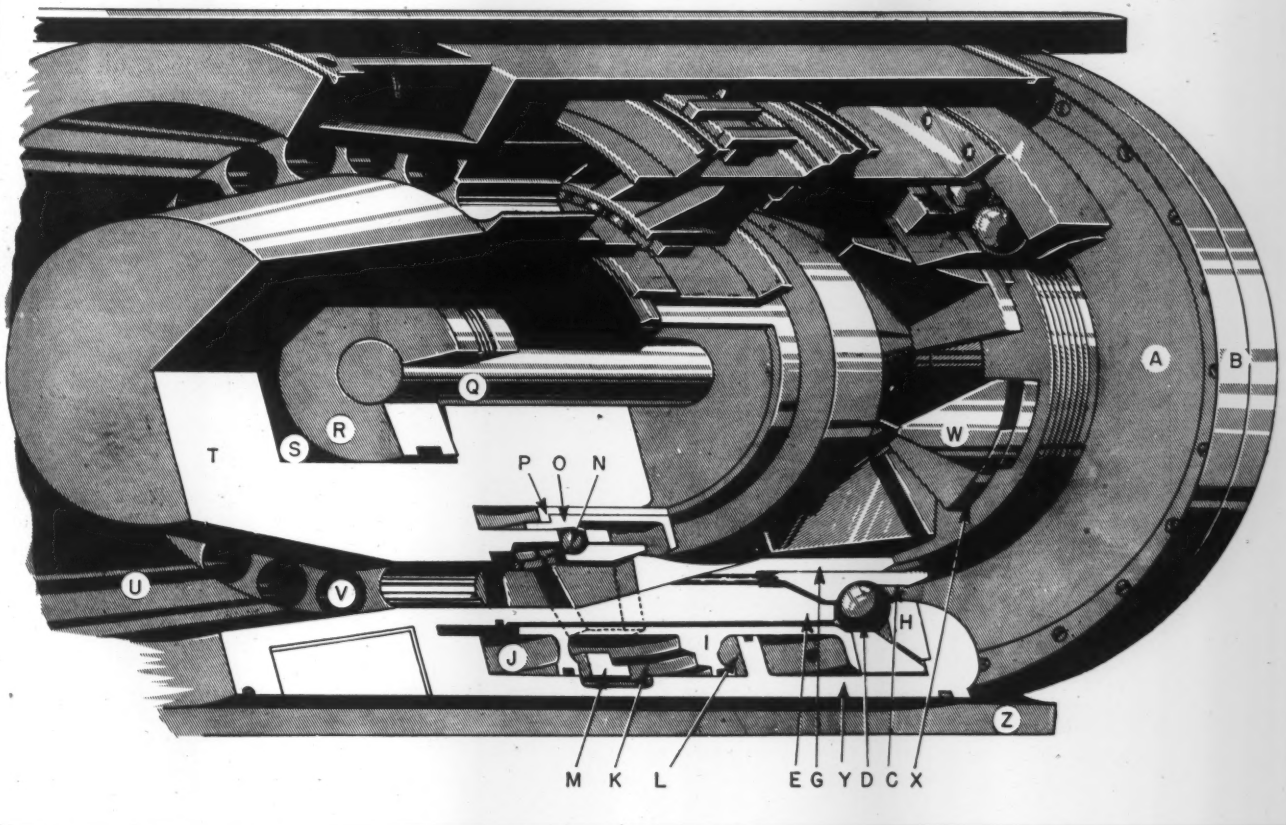
Should relatively slow release be desired, no pressure is applied to the release sleeve chamber, and the shuttle slide lip, also moved by the central hydraulic cylinder, withdraws the release sleeve by direct contact until the piston locking balls reach the brink of the tapered section of the release sleeve. The system becomes unstable at this point and release occurs exactly as in a single-stage ball release.

In the design of the mechanism and the piston structure itself, full advantage was taken of the fact that premature release of the piston, although involving an amount of energy equivalent to an explosion, would not be hazardous to personnel since the effect would be no more severe to the rest of the gun than that of the shot which was in progress. Consequently, the safety factor used in proportioning the affected parts is very close to unity. The saving in piston weight which this permitted is a major factor in extending the performance capabilities of the gun. On the other hand, the external gun parts containing the air pressure were designed with safety factors commensurate with the hazards of failure and subjected to proof load tests.

The release mechanism parts against which the balls rest were of necessity designed for relatively short life, since the total load to be sustained is fixed by the working pressure (1000 psi) required to attain the desired performance, and the space available was limited by the diameter of the barrel forging and the piston. Although brinelling of the mating surfaces would begin to occur at about 30 per cent of the maximum working pressure, extrapolation of the loading found permissible in the earlier 5.6-inch and 15-inch guns indicated that satisfactory (50 to 1000 shots) life of the piston link would result if the load were spread over 30 one and one-half inch diameter balls. The geometry of the loading is such that the piston link, which is accessible after each shot for inspection and replacement if necessary, is much more severely loaded than the rela-

Fig. 3—Below—Cutaway view of piston release mechanism

A- PISTON BASE
B- PISTON GASKET
C- PISTON LINK
D- PISTON RETAINING BALLS
E- BALL CATCHER
G- INNER BALL CATCHER
H- THRUST RING
I- RELEASE SLEEVE
J- OIL CHAMBER FOR COCKING RELEASE SLEEVE
K- OIL CHAMBER FOR STOPPING RELEASE SLEEVE
L- OIL CHAMBER FOR RELEASE SLEEVE
M- STOPPING UNIT FOR RELEASE SLEEVE
N- RELEASE-SLEEVE RETAINING BALLS
O- SHUTTLE
P- SHUTTLE SLIDE
Q- HYDRAULIC PISTON ROD
R- HYDRAULIC PISTON HEAD
S- DOUBLE ACTION HYDRAULIC CYLINDER
T- HYDRAULIC CYLINDER HOUSING
U- MAIN AIR CHAMBER
V- AIR PASSAGE VENTS
W- WIND SPLITTER
X- ORIFICE PLATE
Y- RELEASE MECHANISM HOUSING
Z- GUN BARREL



tively inaccessible release sleeve insert and thrust ring; the latter parts consequently have service lives several times longer.

It was found in the smaller guns that the load which could be applied to the surfaces contacting the balls varies with the 1.65 power of the ball diameter for approximately equal local damage; this figure is about the same as that used in ball bearing calculations in their loading range, which is of course below the brinelling point.

It was felt that a system in which multiple rows of balls would reduce the unit loading to the point where no plastic deformation would occur might encounter serious difficulties in securing equal load distribution and simultaneous release; one of the major advantages of the ball release is that very uniform loading is obtainable with only ordinary precision of construction, since all mating parts are cylindrical and the readily available commercial balls are of high uniformity of dimension.

Loadings Determined by Strain Gage

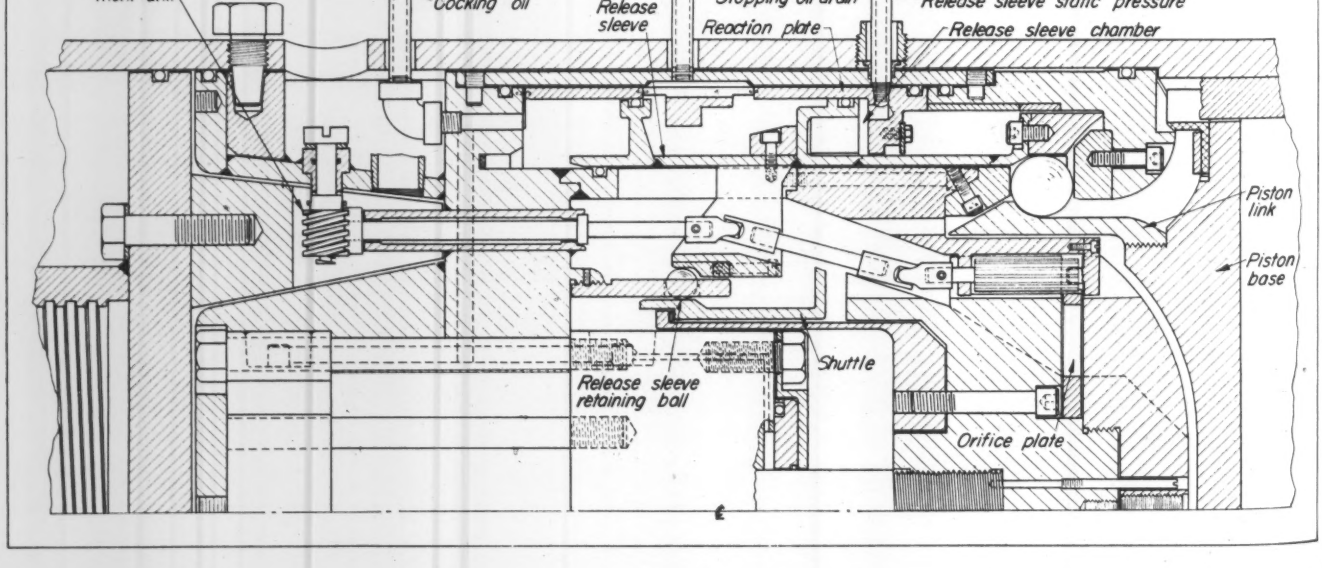
In the actual development of a workable design, reasonably precise knowledge as to the load distribution in several critical locations was necessary. For example, the release sleeve had to be relatively thin in order that an internal member, the inner ball catcher, could be made large enough to retain the balls after a shot in a position where the nose of the release sleeve could plow them back into position when inserted for the next test. The compressive hoop stress in the link from the angular loading of the balls is very high, and is combined with the tensile load of the air force on the piston. Resistance-wire strain-gage studies of the distribution of this load along the link were therefore made on the corresponding 15-inch air gun parts under compression testing machine loading. It was found that the load so spread itself along the link that an assumption that the entire section of the link behind the contact point carried the hoop loading was conservative, and that the link could be proportioned with confidence for positive ball retention. Similar studies were made on the release sleeve.

Arrangement of the various pressure chambers for air and oil used for cocking, locking and releasing the mechanism required a great number of seals. In most cases, O-ring gaskets were selected; in fact, the design of the two-stage mechanisms would have been virtually impossible without the compact, two-way seal which O-rings provided. Had bolted-on cup gaskets been used, for example, the resulting increase in length and weight of the release sleeve would have nullified the quick-release advantage gained by the extra release stage.

In determining the dimensions of the various parts, an unusual complication arose in connection with the use of O-rings. Since some of the parts serve as highly stressed pressure vessels of large diameter, the strain which takes place is enough to cause dimensional changes affecting the O-ring seal. In addition, under some conditions of operation, the pressures inside and outside a part may be exactly reversed, thus doubling the total strain. It was necessary to choose compromise dimensions which would insure a seal under all conditions; in one case extra metal was added to a part to reduce the strain.

Some additional complication in the shape of parts resulted from the necessity for providing for relatively unobstructed flow of air through the mechanism during piston travel. At the same time, all spaces not necessary for air flow or movement of the parts were filled up or blocked off with solid metal to reduce the minimum air chamber volume obtainable and thus increase the performance range of the gun. The design problem here was to locate this filler material on stationary rather than moving parts so that the weight would not affect the performance.

Fig. 4—Below—Cross section through release mechanism shows detail of geared unit for turning orifice plate



As a result of experience with earlier mechanisms, the use of large-diameter screw threads to hold parts together was avoided wherever possible, and large numbers of small alloy-steel screws substituted even though a design somewhat less neat might result. The jamming of such threads due to galling or slight deformation had been a frequent source of trouble, and interchangeability of spare parts was difficult to obtain. In the case of the piston link atachment, only threading could carry the load; interchangeability was secured by using a male-female thread gage.

Parts Designed for Safe Failure

Since the low factor of safety used in many of the parts made occasional failures likely, every effort was made in the design to minimize the consequences. For example, all external sharp corners on hardened steel parts were carefully avoided; previous experience had demonstrated the serious effects that can result from the "paring" effects of such corners on adjacent unhardened parts.

Materials and methods of construction selected were influenced by the fact that only one mechanism was to be built, and this in turn frequently affected the design. The main body of the mechanism was kept as simple in shape as possible since it was to be fabricated by welding rather than by casting as it might have been in a production item. The strongest available weldable alloy was selected for the release sleeve body, the housing sleeves, and other highly-stressed parts so that they could be machined from rolled-up, welded hoops. Since these form pressure vessels, stress relieving and radiographic examination were specified. With material and fabrication reliability assured and overstressing guarded against by pressure relief valves, a working stress of 75,000 psi was usable in SAE 4130 steel.

The critical parts coming in contact with the steel balls were made from solid forgings of a nondeforming high-carbon die steel similar to SAE 52100, since the ball loads are so great that they would break through any case-hardened surfaces. It has been found that stress relief at 375 F after hardening is absolutely essential for such parts if brittle fracture is to be avoided without reducing the hardness below the Rockwell C 59-61 range, which must be maintained for satisfactory part life; should the hardness fall below C58, rapid local failure will result.

One of the trickiest assembly problems involved the release sleeve and the reaction plate *Fig.* 4. It was necessary to weld on the final parts of the release sleeve after the reaction plate had been slipped in place. The finish-machined mating surfaces were protected from distortion by a temporary internal stiffening plate, welded in place and machined away after assembly. An O-ring groove in the reaction plate was then formed by a separate bolted-on ring so that the rubber gasket, which would have been destroyed by the welding heat, could be inserted later. Had this been a production job, the joining of these interlocking parts might well have been done by copper-hydrogen brazing, and the "spokes" joining the inner and outer sections of the release sleeve made separately and so attached rather than being machined from solid plate.

The 21-inch air gun was designed by the same personnel responsible for its operation, calibration and maintenance. This meant that first-hand knowledge of the value of various operating features was available and the design was considerably influenced thereby. For example, all adjustments may be made by one man and without any disassembly or switching of parts, since it was found that the variety of tests performed made rapid adjustability essential. This necessitated a geared, universal-jointed shaft arrangement for rotating the orifice plate shown in *Fig.* 4, which controls the flow of air through the mechanism following release of the piston.

TABLE I

21-inch Air Gun

Dimensions and Operating Capacities

Bore of gun	21 in.
Length of barrel	93 ft 6 in.
Weight of gun	35,000 lb
Volume of chamber	1 to 10 cu ft
Volume of barrel and muzzle tank	385 cu ft
Working pressures (maximum):	
Chamber	1000 psi
Muzzle	150 psi
Release sleeve	1000 psi
Maximum force on piston	340,000 lb
Weight of empty piston	120 lb
Maximum acceleration of piston	2500*g*
Maximum velocity of piston	700 ft per sec

Dry Plating Method Developed

A PROCESS of metal plating by means of a gaseous medium has been developed by The Commonwealth Engineering Company of Dayton, Ohio. Heat is the sole means of deposition in the process, involving the thermal decomposition of metal carbonyls in an inert atmosphere of carbon dioxide.

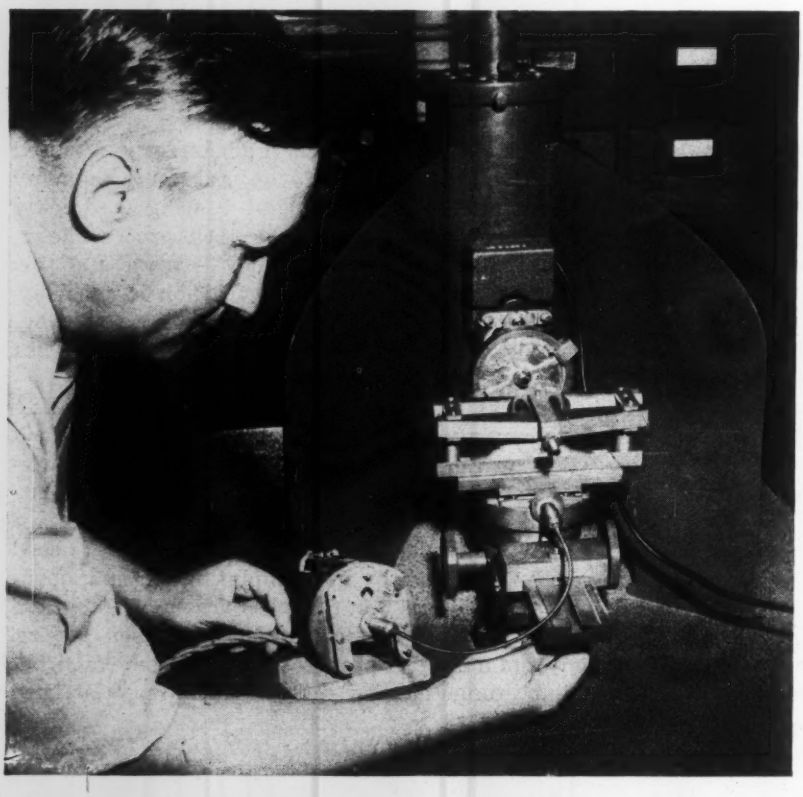
Objects to be plated are radiant-heated in a plating chamber fed by a metal carbonyl generator in a closed system which recycles the plating gases for economy of operation. An integral metal coating is quickly obtained at approximately 400 F, the process being applicable to any material which will withstand this temperature. Rate of uniform deposition is considerably higher than that of conventional electroplating, and irregular surfaces, complex shapes and articles with internal areas are readily handled.

The process is ideally suited to continuous plating of strip moving at fairly high speeds. In one such operation an amount of metal which would have required thirty minutes to apply by conventional plating methods was deposited in four seconds. Thus a web of fine, hard paper moving at a substantial speed can readily be coated by the gas plating method, opening new possibilities for the production of foil laminates, can making materials and condenser papers. Carbonyls of a number of metals, including nickel, iron, chromium, tungsten and molybdenum, may be used in the process.

Scanning THE FIELD for Ideas

Fatigue damage in metals may be detected before actual fracture occurs if methods being developed at the National Bureau of Standards are perfected. They involve the measurement of interatomic spacing of crystals by means of X-ray diffraction. Because a crystal deforms under the influence of an applied stress, with a resultant change in the interatomic spacing, X-ray diffraction can be utilized to determine the magnitude of strain in the crystal. This deformation, however, is limited to the elastic range of deformation of a metal. Plastic deformation, which involves slipping of the atomic planes, does not change the dimensions of the crystal lattice. For this reason the diffraction method is limited to the elastic portion of metal deformation.

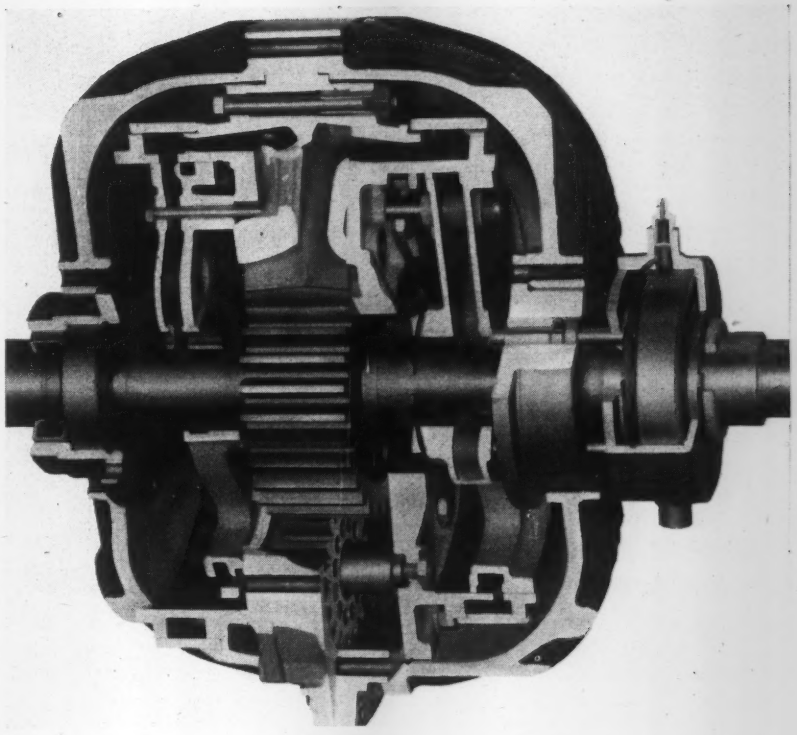
Shown left below is the Bureau's apparatus for the measurement of strain which will be used in an effort to correlate the progress of fatigue damage with surface strain measurement. The X-ray beam, emerging through a pin hole at the center of a circular film holder, is diffracted by the crystals of the metal specimen mounted under tensile stress directly in front of the film holder. The diffracted beam is recorded on the film located behind aluminum foil in the holder. Measurement of the diffraction rings thus recorded permits a determination of the strain in the specimen. The motor in the foreground moves the specimen horizontally during the exposure.



Because the length over which the strain is measured can be very small it is unnecessary to make measurement on unstrained metal. Also, the strain is measured in a very thin surface layer. Most serious disadvantage of the method has been its lack of sensitivity, due to imperfections in the metal crystal. Use of the method for fatigue studies will be based upon previous findings that specimens, damaged by fatigue stressing, have shown less surface strain than if the metal had not been subject to fatigue stress.

Hydrostatic coupling designed by Thomas Hydraulic Speed Controls Inc., delivers infinitely variable torques and speeds in transmitting power. The power transmitted is controlled by the position of a metering valve which proportions the amount of fluid or air admitted to a multiple-gear pump.

Sun gear of the pump is keyed to the output shaft and the input shaft is flange mounted on the coupling housing which carries the planet gears. Resistance to pumping action between the sun and planet gears determines the speed and torque transmitted in this unique drive shown at right in cutaway view. The relative rotation of the shafts provides the pumping action, resulting in the flow of air and oil through a system of ports controlled by the metering valve. The two fluid media are used independently or in controlled mixture determined by the axial position of the valve which meters the flow through suction and discharge ports.

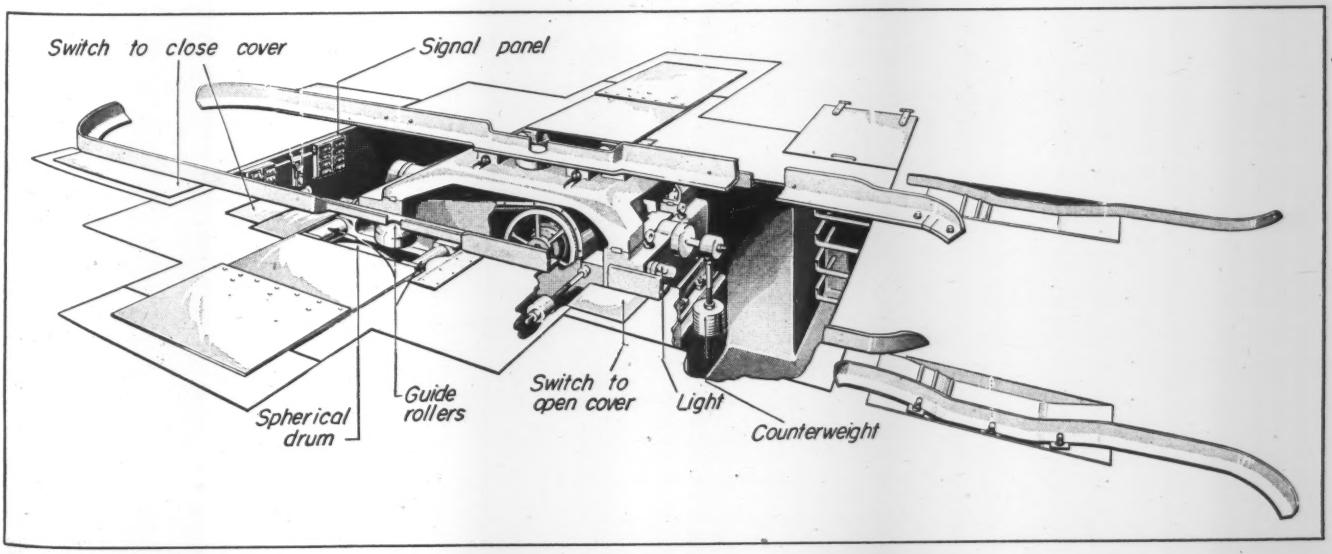


Torque drawn from the prime mover never exceeds the demand torques of the driven machinery and may be reduced to zero quickly by full flow of air through the pump. Fluid flow is negligible when the drive is fully engaged. While operating in this position all working parts within the drive have only slight relative motion. Fluid cushioning of the power absorbs and dampens shock loads and slip, when the drive is fully engaged, amounts to less than 2 per cent.

Operation of the coupling depends upon maintaining clearances and tolerances to a minimum. The gears operate with 0.003 to 0.004-inch total allowable diametrical and side clearance.

Alignment of front wheels for Ford, Mercury and Lincoln cars is quickly and accurately adjusted on the "roadability gauge" shown diagrammatically below. Invented by Edwin Pleasance, the device is designed to obtain a neutralized thrust on the front tires. Three guide rollers maintain each wheel of the car on top of spherical drums which drive the front wheels at 30 miles per hour. Being mounted in gimbals, the rolling spheres are free to swing sidewise when the path of the tire tends to cut a helix across the normal path of the sphere. At such times the spheres will attempt to roll about their longitudinal axes but are restrained from continuous motion by 100-pound counterweights.

When tires are tracking neutral the spheres return to their normal position. This position is indicated by a light on the operator's control panel. Toe-in and toe-out conditions are also indicated by



lights, showing the direction of correction required. These rolling spheres are so sensitive that they will follow the exact path of the wheels, tracking to within close limits. They are not affected by any wheel wobble or other misalignment of the wheel assembly but rely solely upon the path created by the rolling tires.

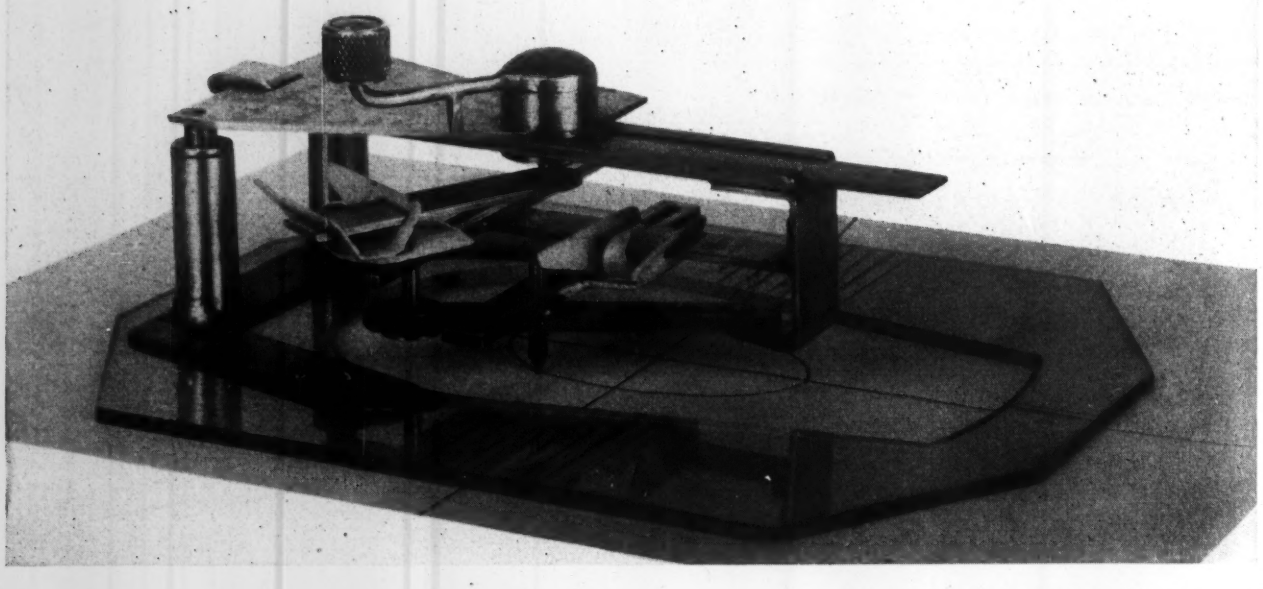
To protect the spheres from the thrust of the rear wheels as they pass over the unit, a cover automatically closes over them as the front wheels leave their position. The wheels of the next approaching car operate a switch, opening the cover again to receive them for testing.

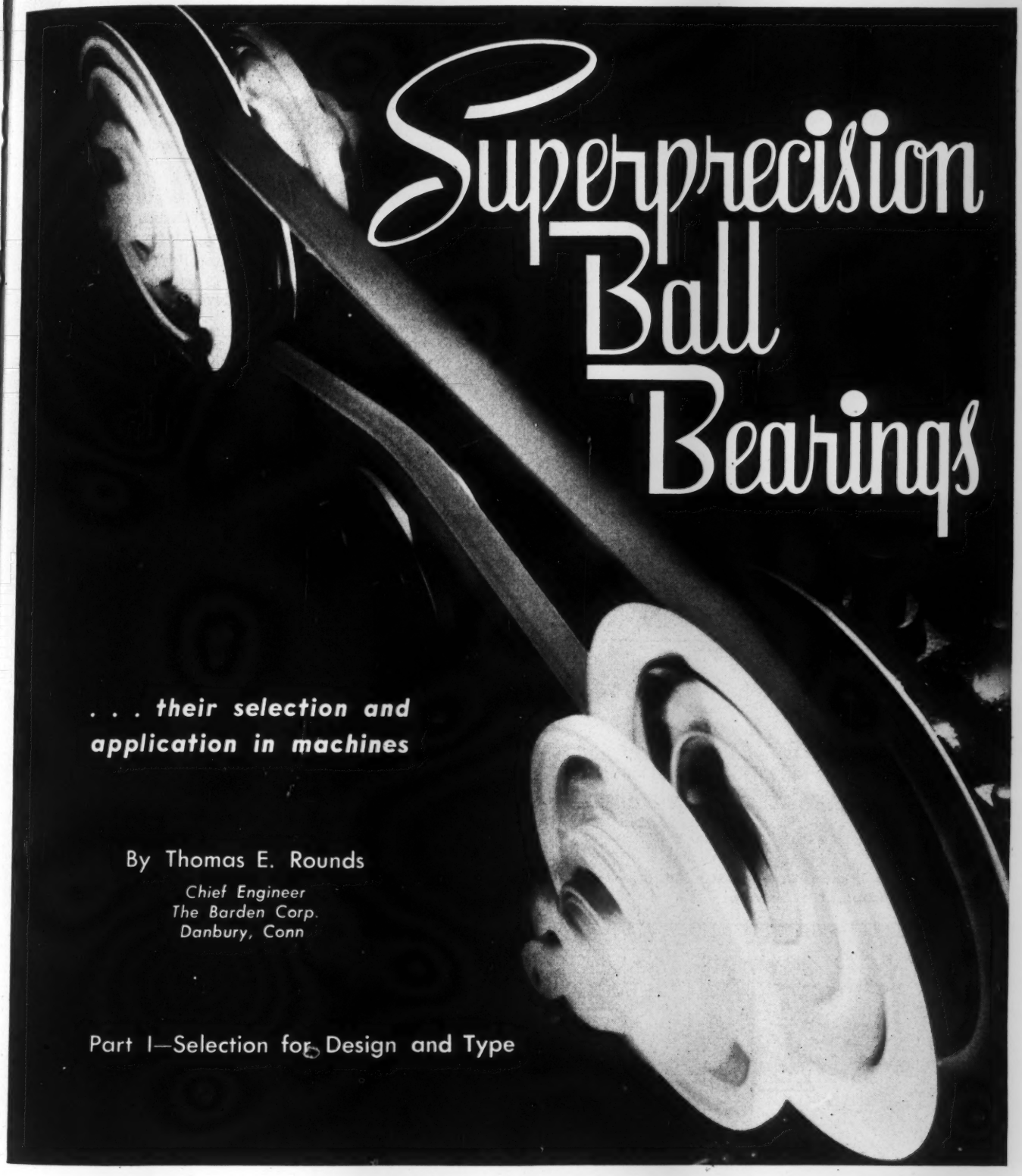
Ellipses usually require awkward and time consuming methods of construction on a drawing, particularly if an accurate projection of a circle is required. The ellipsograph illustrated below, however, makes construction practically as simple as drawing a circle with a compass. An experimental model, designed and patented by Franklin Gase, the instrument requires only two adjustments to draw any ellipse within its range of 0 to 2½-inch major diameter and 15 to 50 degrees of inclination of projected circle.

Consisting of links with pivoted and sliding members, the instrument describes a perfect ellipse on a given pair of axes without need for locating any other reference points. The minor axis, however, shifts with change in inclination as indicated on the base of the instrument on which the complementary angle is marked in degrees. One turn of the crank generates the ellipse. Other useful features incorporated in this ellipsograph include tilting the ellipse axes without tilting the base, and dividing the circumference into degrees of circular arc without reference to tedious and conventional constructional methods.

Chemical heating of the soldering iron shown above is obtained from a cartridge containing metal powder, an oxidizing agent and a primer cap. With the cartridge inserted in the iron in a socket behind the soldering tip, heat is developed within five seconds by tripping a firing pin in the handle. A pointed rod strikes the primer, starting the heating action. The heat developed in this iron manufactured by the Kemode Mfg. Co. is the equivalent of almost 200 watts, supplying soldering temperatures for about ten minutes.

In the September issue of this section the illustration of a swiveling wheel showed a Cessna 140, not a DC-3. The same principle of castering for cross-wind landings has been approved for the DC-3.





Superprecision Ball Bearings

. . . their selection and application in machines

By Thomas E. Rounds

Chief Engineer
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Danbury, Conn

Part I—Selection for Design and Type

A VAST amount of material has been published on the subject of the proper selection, application and servicing of rolling contact bearings. Handbooks published by the various well-known manufacturers are replete with descriptive material, formulas, and application drawings as well as maintenance and replacement instructions. As a result most users have developed a certain "respect" for the proper care and attention necessary to produce satisfactory results from these accurate mechanical subassemblies. Relatively few, however, outside of those engaged in the production of extremely accurate machine tools and precision instruments, realize the full capabilities and accuracies attainable from the use of superprecise bearings when proper selected, applied, protected and lubricated.

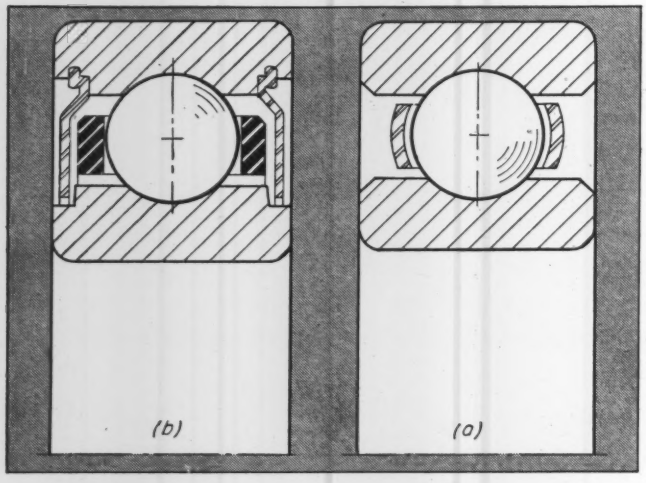
It is the intent of this series of articles to emphasize certain points which deal, first, with those phases of selection, bearing design and bearing mounting. and second, with those installation practices and

techniques which most seriously affect ball bearing performance. Some subject matter which is already well understood by the majority of users has been intentionally omitted, other subject matter which may seem to be overemphasized is included because it has a vital bearing on selection and application.

Although considerable further investigation of certain characteristics of ball bearings and their operation remains to be done, it is hoped that readers will find these articles of assistance in solving their bearing problems.

Standard tolerance classifications of bearings, based on dimensional tolerances, defines the standard grade as ABEC-1, the selected grade as ABEC-3 and the superprecision grades as ABEC-5 and ABEC-7. While many types of ball bearings are made commercially, relatively few of the types lend themselves to being produced to superaccurate limits. These articles, based on experience gained not only in the manufacture of bearings but also from observations of successful installations in the field, will discuss principally the superprecision grades ABEC-5 and ABEC-7.

Fig. 1—Regular single-row, deep groove Conrad type bearing (a) and single-row, deep-groove Conrad double shielded type (b)



TYPES: As classified by groove design, there are in common use today only eight fundamental types of ball bearings. These are generally as follows:

1. Deep-groove, Conrad with uninterrupted raceways 2. Angular-contact, nonseparable, low or high angle 3. Angular-contact, separable outer ring, low angle	Single-row, radial thrust bearings for single or duplex mounting
4. Filling notch or loading groove	
5. Double-row, rigid 6. Double-row, self-aligning	Double-row, radial thrust bearings
7. Thrust bearings, one direction 8. Thrust bearings, two direction	Thrust bearings (non radial)

Single-Row, Radial and Thrust Bearings, Single Mounting

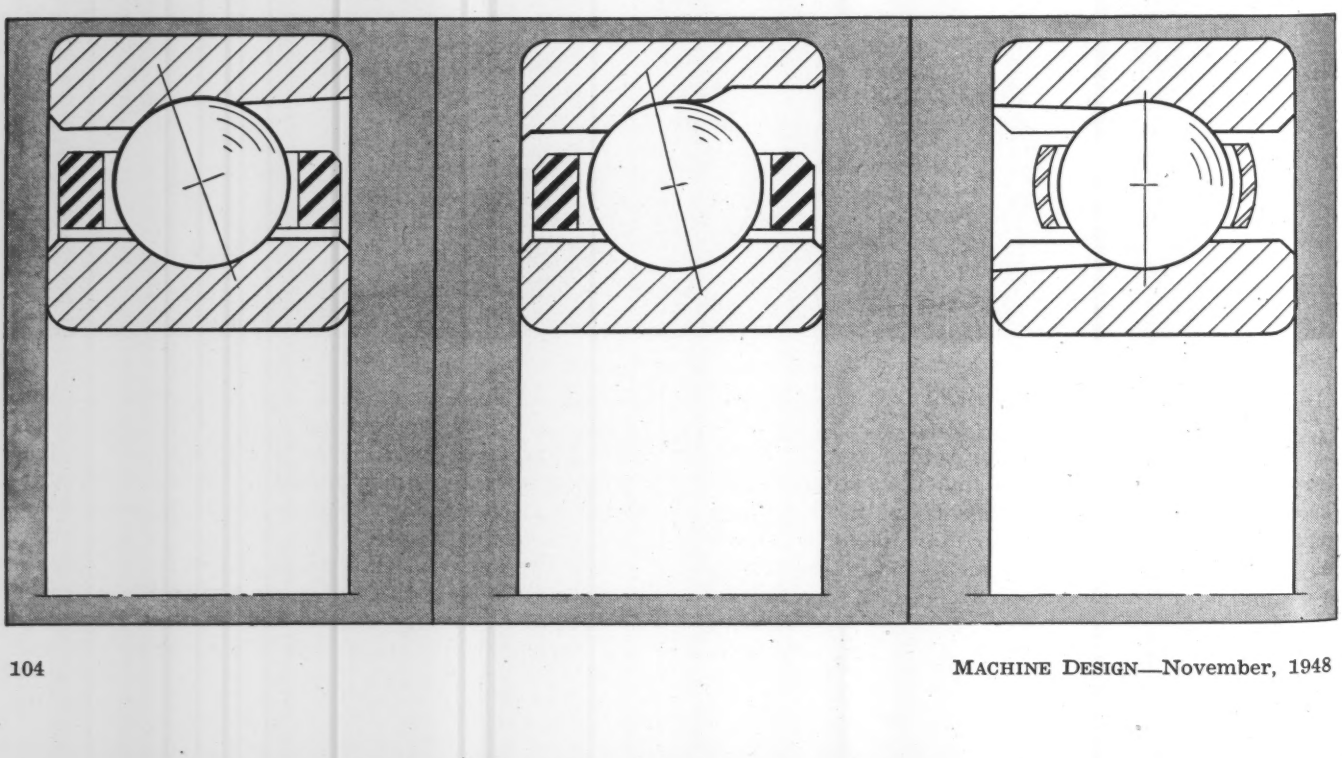
DEEP-GROOVE BEARINGS: This type of bearing is probably the most widely used type in industry today, *Fig.* 1*a*. It is certainly the most versatile. The raceway rings are symmetrical and of uniform section, providing not only maximum strength but the least tendency toward distortion in heat treatment and subsequent grinding. End thrust may be taken in either direction. For most applications therefore, it is the simplest in design, since it is self-contained and need not be used in an end-thrust loaded, opposed or adjusted mounting, as is generally the case with unidirectional thrust type bearings.

Deep-groove bearings may be supplied with a variety of internal fittings or loosenesses, a variety of retainer designs and also with shields to exclude

Fig. 2—Typical single-row, angular contact nonseparable bearing

Fig. 3—Typical single-row, angular contact separable bearing

Fig. 4—Typical single-row filling notch or loading groove bearing



foreign matter. These bearings are used under a wide range of conditions ranging from those involving low friction at low speeds to rotation at high speeds under a wide variety of loading conditions.

Therefore, if the application is simple and heavy end thrust is not involved, and if extremely accurate endwise shaft location control is not needed, the deep groove bearing will usually be the logical choice.

DEEP-GROOVE SHIELDED BEARINGS: Considerable effort has been directed in recent years toward the development of shielded, *Fig. 1b,* or sealed bearings which will run satisfactorily at very high speeds. While a large variety of sealed bearings has been produced, relatively few of them are successful at very high speeds due to the difficulties associated with rubbing contact of the sealing materials used, and the fact that due to space restrictions it is difficult to incorporate both seals and high-speed composition retainers. Also, the method of attachment of the sealing members to the outer ring usually results in distortion which militates against true precision characteristics in the bearing.

The shielded bearing, however, has been developed in many sizes to the point where high-speed composition retainers can be used and the shielded members are so attached to the outer ring that negligible distortion of this member results. Furthermore, the quality of lubricating greases has also been improved so that unless temperatures are extremely high excellent results are obtained, even at speeds approaching those found possible with unshielded bearings.

This type of bearing may also be furnished with one shield only and in duplex preloaded pairs. On preloaded pairs, the shields are applied usually to the outside faces of the pair only.

ANGULAR-CONTACT, NONSEPARABLE BEARINGS: This type of bearing, *Fig.* 2, should be divided into two or more subdivisions based on contact angle and, therefore, by thrust capacity. The designer must, for this reason, decide largely on the basis of loads and speeds involved whether a moderate-angle bearing (under 25 degrees), suitable for light thrust in combination with radial load or whether a steep-angle bearing (over 25 degrees), suitable for heavy thrust and moderate radial load is indicated.

For most precise applications, such as accurate machining or grinding spindles, heavy end thrust is unusual and the requirement is ordinarily for maximum radial rigidity. Consequently, the moderate-angle bearing is most frequently used. The high contact angle, while providing maximum axial rigidity, generally militates strongly against the ability of the bearing to operate at high speeds. The limitation to the lower speed ranges for steep-angle bearings is inherently due to the development of increased slippage near the edges of the contact areas and the resulting tendency toward spinning action of the ball about its contact axis. For reversing thrust loads, mounting in opposed pairs is always necessary.

ANGULAR-CONTACT, SEPARABLE BEARINGS: This type, familiarly known as the separable or "magneto" bearing, *Fig.* 3, is designed to be separable into the component elements of inner and outer rings, balls and retainers. While this type was quite popular at one time for very high-speed spindles, its use

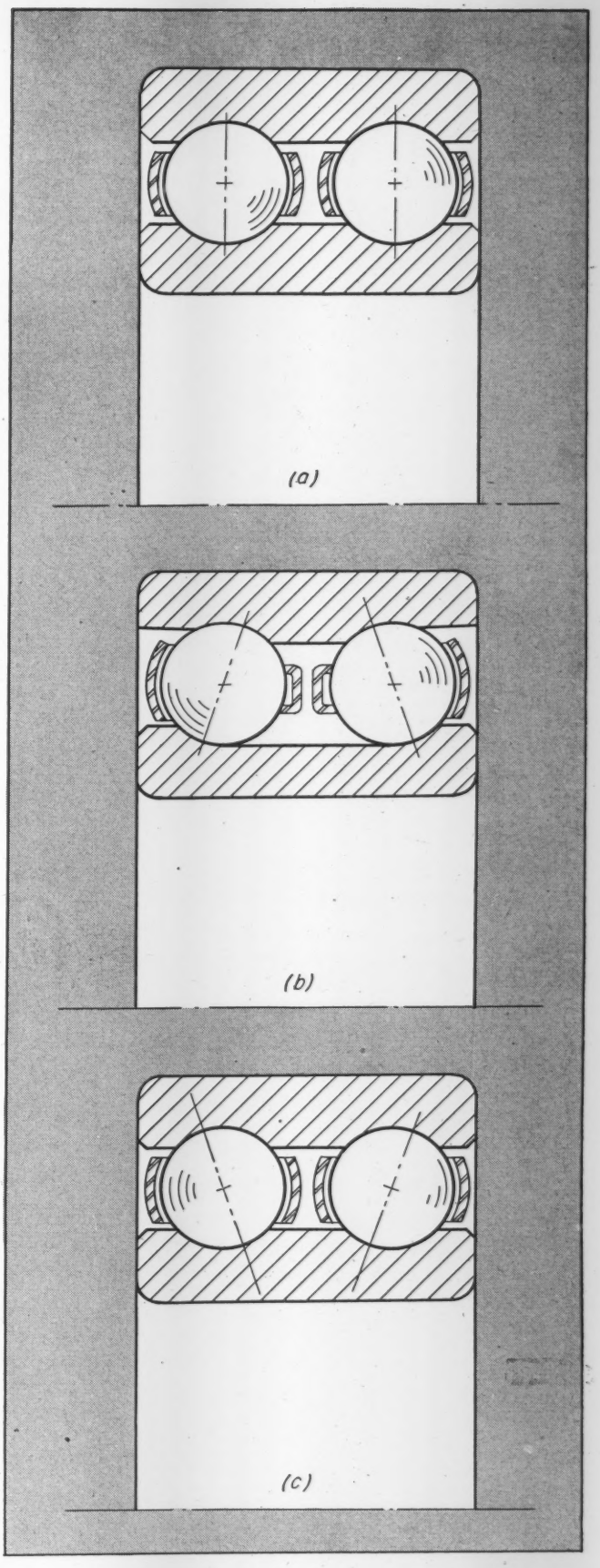


Fig. 5—Double-row rigid bearings of the radial contact type (a), divergent contact type (b) and the convergent contact type shown at (c)

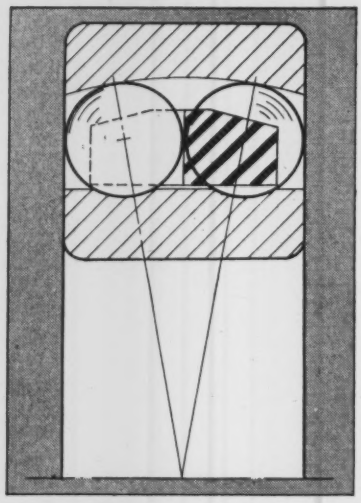
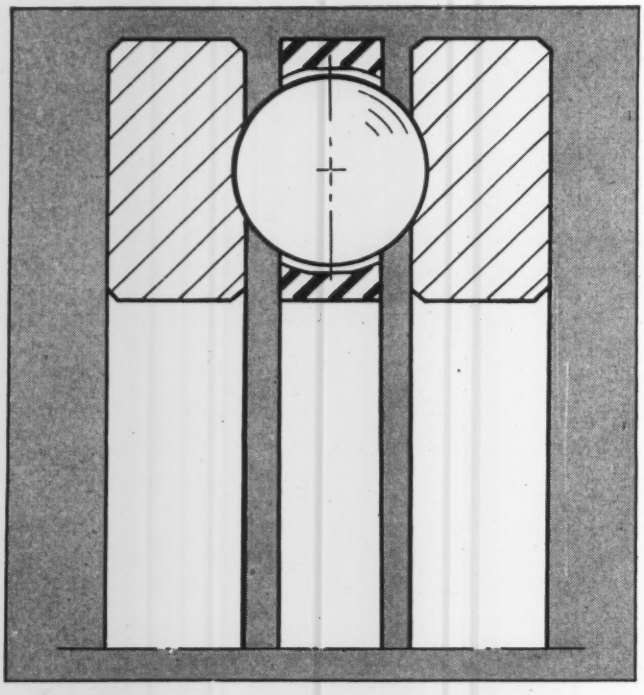


Fig. 6—Left—Double-row, self-aligning ball bearing with spherical outer race

Fig. 7—Below—Plain thrust bearing of the unidirectional type



has not grown apace with that of the nonseparable bearings described in the foregoing. The separable characteristics present no great advantages, since frequently the lack of "self-containedness" and the contamination due to dirt make installation practices difficult if not hazardous. Contact angles used for this type are low due to the necessarily shallow grooves.

Separable bearings are available generally only in the light-duty series for light radial and thrust loads at high speed. Mountings using opposed pairs are necessary for reversing thrust loads.

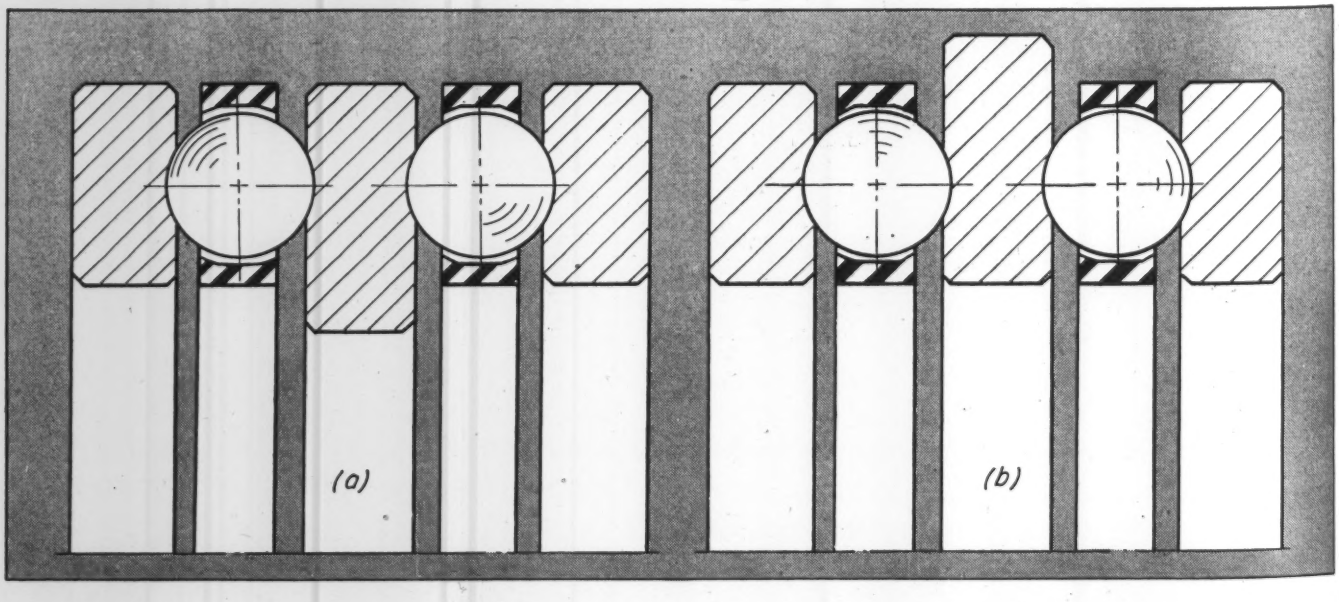
FILLING NOTCH OR LOADING GROOVE BEARINGS: This type of bearing, *Fig.* 4, was originally made for the purpose of providing some additional radial capacity over that afforded by the Conrad bearing. The added complement of balls, usually 3 or 4 in number, would appear to give increased load capacity in proportion to the added number of balls. However, any increased capacity is largely offset by the fact that, as loads are increased, the filling slots interfere with the continuity of contact, particularly under thrust loading.

Since this type of bearing is nonsymmetrical, it is not inherently suited to precision work. This type tends to be somewhat noisy and rough running and, because the ball retainer design is limited to metallic materials for reasons of space restriction, it is generally not seriously considered for accurate spindle or instrument work. This type of bearing is not suitable for duplex mounting arrangements.

Double-Row, Radial Thrust Bearings

DOUBLE-ROW, RIGID BEARINGS: This type of bearing, *Fig.* 5, is most generally available in the opposed angular contact construction. Except where high speeds are involved, it is quite generally useful and successful. There are two main features which should be carefully noted. The primary feature is the added radial capacity afforded by the second row of balls. A secondary feature of the angular contact

Fig. 8—Plain type thrust bearing for two-directional service with small-bore center ring (a) and large-bore center ring (b) for special applications



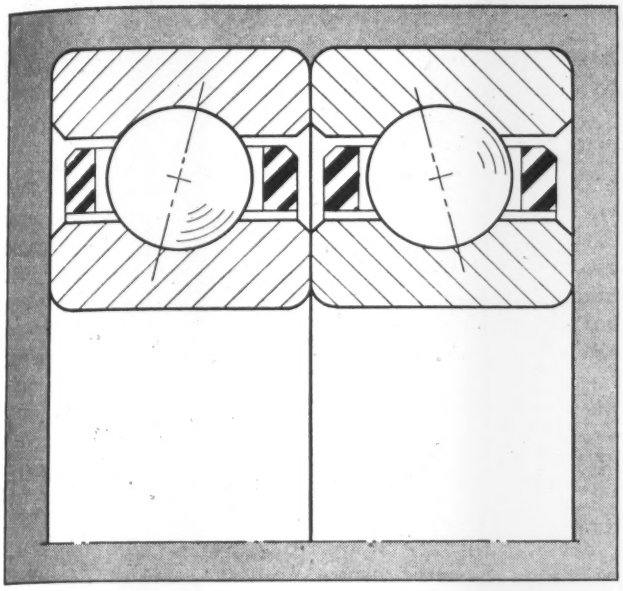


Fig. 9—Two bearings of type shown in Fig. 1, single-row, deep-groove, arranged as duplex pair back-to-back or DB preload

types, *Figs.* 5*b* and 5*c*, is that of substantial endwise rigidity and axial control of shaft position with minimum or zero end play. The end-thrust capacity, however, is about equal to that of the single-row angular-contact (steep angle) bearings of the same size and series.

With different manufacturers, the angular construction of the double-row bearing varies, depending upon whether the load lines converge or diverge toward the center axis of the shaft. However, because double-row bearings are sensitive to misalignment, the shaft must be stiff and free from appreciable deflection.

Insofar as speed is concerned, the operating ability of the double-row rigid bearing is about the same as that of the single-row, steep angle bearing.

SELF-ALIGNING BEARINGS: The double row self-aligning bearing, *Fig.* 6, with its spherical outer ring raceway was first designed for machines of relatively flimsy construction where bearing alignment was poor or of such indifferent nature that a rigid or nonself-aligning type bearing of any type would not stand up. The chief disadvantage of this bearing is its low end thrust capacity and high susceptibility to brinnelling action between balls and raceways under shock loading. For this reason, considerable care must be taken in installation to avoid damaging the balls and raceways.

The radial capacity of the double-row self-aligning bearing is about the same as deep-groove bearings of comparable size and series. Speedability is generally limited by the retainer construction. Where composition retainers are available, this type will operate at speeds of the same magnitude as those obtainable with deep-groove bearings having composition retainers.

Thrust Bearings

ONE-DIRECTION THRUST BEARINGS: Where pure thrust load only need be considered, this bearing

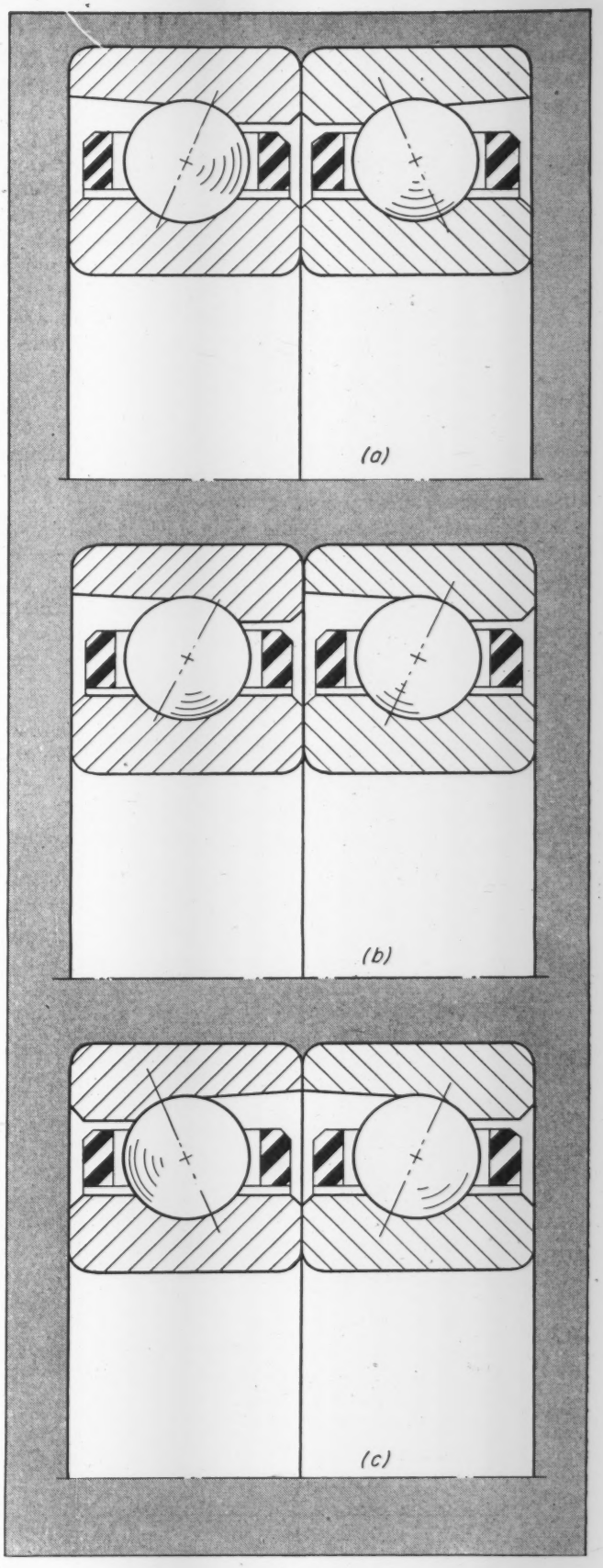


Fig. 10—Two bearings of the type shown in Fig. 2, single-row angular-contact, arranged as duplex pair back-to-back or DB preload (a), face-to-face or DF preload (c), and tandem match or DT preload (b)

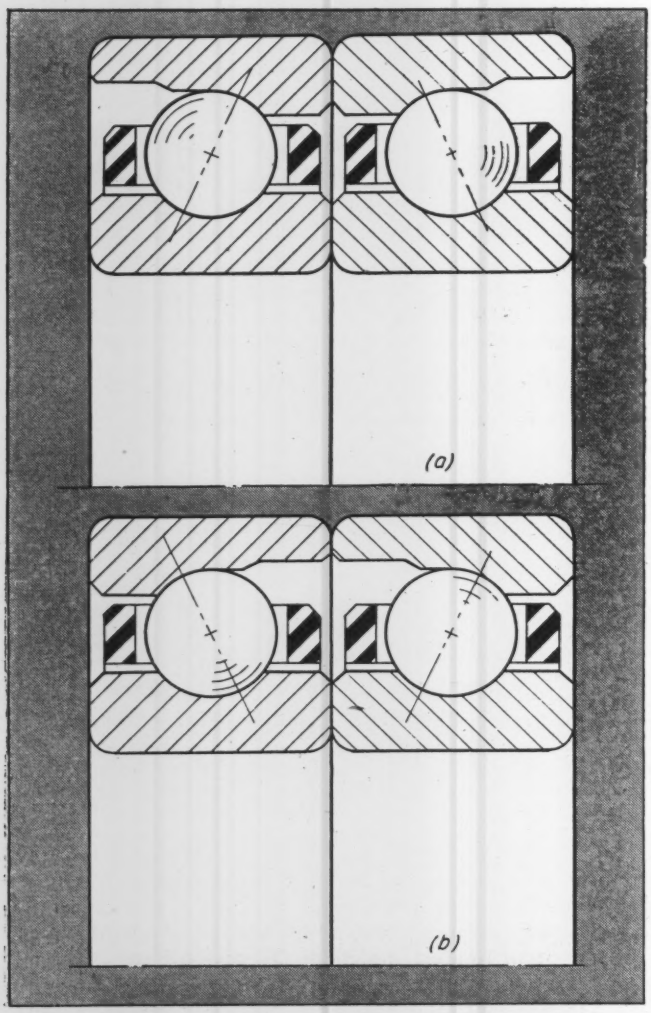
is useful and reliable, but only at low speeds, *Fig.* 7. This is due to limitations imposed by allowable centrifugal forces on the balls, resulting in high contact slippage factors. Since the contact angle is 90 degrees and therefore parallel to the shaft axis, a very high degree of axial rigidity is available. However, alignment must be of a high degree of refinement. These bearings must be either continuously loaded with end thrust to avoid ball skidding, or loaded by adjustment against another bearing with thrust capacity. Spherical seating washers sometimes are supplied, but are seldom used in modern machines.

TWO-DIRECTION THRUST BEARINGS: This type is seldom encountered in modern machines due to its excessive space requirements and the elaborate mounting arrangements required, *Fig.* 8. The same speed restrictions apply as in the case of single-direction thrust bearings.

Both single and double-direction thrust bearings have generally been superseded by angular contact bearings of the low and steep-angle types, due to the space saving afforded by their combined radial and thrust capacity and higher permissible speeds.

For slower speeds, however, two-direction thrust bearings have been used within the last several years to a somewhat greater extent where the main requirement is extremely rigid control of the shaft movement axially.

Fig. 11—Bearings of the type shown in Fig. 3, single-row angular-contact separate outer ring, arranged as a duplex pair back-to-back or DB preload (a) and face-to-face or DF preload (b)



SINGLE ROW, RADIAL AND THRUST BEARINGS, DUPLEX MOUNTING: Three of the four types of bearings discussed previously for single mounting are also available for duplex "paired" mounting, *Figs.* 9, 10, and 11. Predominantly, the angular-contact types have gained the widest usage, since they have the advantage of increased load capacity afforded by the larger number of balls, the possibility of using one-piece composition ball retainers for high speeds, and a choice of contact angle depending on the amount of the end thrust in relation to the radial loading.

Universal Bearings Simplify Selection

Duplex bearings in the two "opposed" constructions, "back-to-back", *Figs.* 9, 10*a*, and 11*a*, and "face-to-face," *Figs.* 10*c* and 11*b*, are used where reversing thrust loads must be sustained with absence of end play and a high degree of radial and axial rigidity. They are also available in the "tandem" match, *Fig.* 10*b*, for equal division of load between bearings, so that an approximate doubling of radial and thrust capacity is made possible. The development by several leading manufacturers of "universal" or "three-way" matched bearings allows the user to mount the bearings in any one of several ways to suit the particular requirements of the application. For replacement bearings, it is therefore convenient to stock "three-way" matched bearings and suit the requirements of several makes of spindles with one universal bearing specification. Frequently it happens that one size of spindle bearing must be mounted singly, back-to-back, face-to-face, or in tandem on different machines in the same shop or area, and inventories may be kept down by stocking these so-called universal, or "DB, DF, DT" bearings.

As to the selection of the required duplex mounting arrangement, the following principles govern:

1. For absence of end play and maximum rigidity radially and axially, use DB or DF arrangement.
2. For division of end thrust between two bearings, increasing thrust capacity and increasing rigidity, use DT. (Bearings in DT pairs must be externally loaded with end thrust)
3. The DB arrangement is most frequently selected, as the clamping of inner rings is usually essential, and is the best mounting arrangement whether the pair is fixed or floating endwise
4. DF arrangement is less frequently used although considered to be less critical as to alignment requirements
5. For high speeds use single bearings or tandem bearings spring adjusted to remove radial and axial play. For maximum high-speed operation use single bearings.

Duplex bearings must always be kept in pairs as the standard practice is to supply them with matched bores and outside diameters to provide, as closely as possible, uniform load division. Indiscriminate mixing of pairs is not recommended.

The next article in this series, Part II, will cover selection for grade of accuracy and for high speed.

Provides Automatic Load Control

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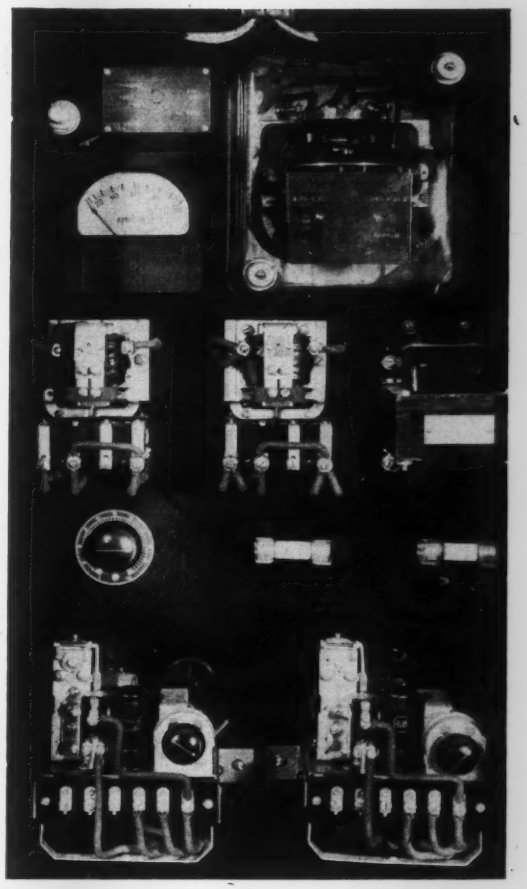
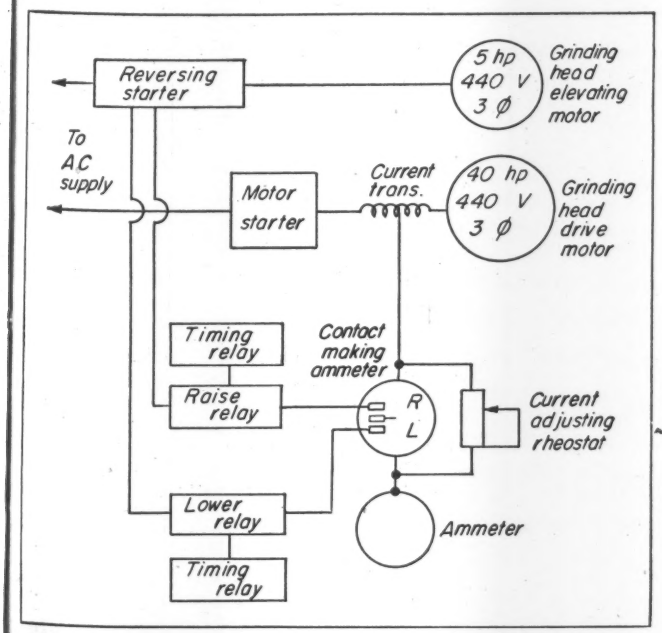


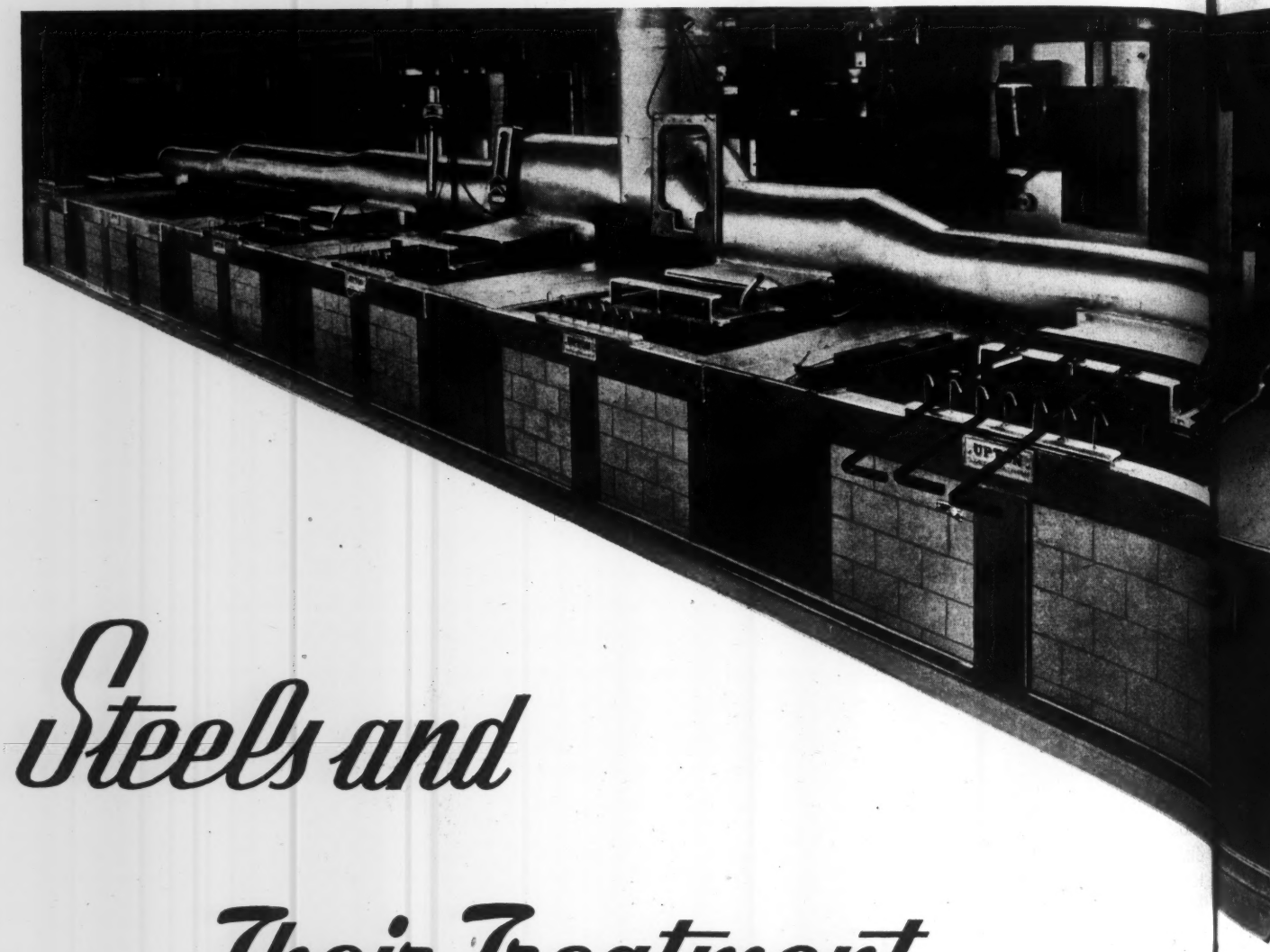
ELIMINATING manual manipulation of pressure settings on a grinding machine, automatic control has overcome many limitations in plate glass production. Designed for Libby-Owens-Ford Glass Co., the control regulates the load on the grinding wheel, reducing the costly damage which often results from the "personal factor" of the less-skilled worker.

Illustrated are the control panel and a block diagram which was developed to adjust automatically the level of the rotating disk-like plate-glass grinding head so as to maintain constant load on the 40-hp driving motor regardless of the irregularities of the plate-glass surface being ground. Heart of the control is a contact-making ammeter, a device similar to an induction type overload relay. This ammeter, operating in conjunction with electronic time-delay relays and control relays, serves to operate the reversing starter of the 5-hp 3-phase grinding head elevating motor.

As the unpolished plate glass passes slowly under the grinding head, the rough surface with its irregularities causes the load on the grinder motor to vary from its preset value, usually full load. The contact-making ammeter, which measures the motor line current, closes its "front" or "back" contact, depending on whether the current is high or low. This momentarily operates the reversing motor starter to energize the small head-adjusting motor thus raising or lowering the grinding head a slight, definite amount. If this does not restore the line current to within limits preset on the contact-making ammeter, the impulse is automatically repeated—after definite time-delay intervals provided by the electronic timing relays—until the preset value is reached. As long as the line current is at the preset value, as selected by adjustment of a small rheostat, the automatic controller remains inactive. The control is electrically interlocked with the grinding-head motor so that it becomes inoperative in the event that the grinding head motor is stopped for any reason.



Worth of this control was proved immediately. Because frequent adjustment of the grinding head pressure by the operator is not necessary, he can give more attention to other duties of the job. The automatic control has eliminated a great deal of the glass breakage which formerly resulted from excessive surface pressure at the grinding head. Uniformity of the ground plates also is improved. All these advantages contributed to increasing the speed of the entire grinding and polishing line.



Steels and Their Treatment

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Part II—Conditioning Processes

HEAT treatments for steels are many and varied, *Fig.* 7, ranging from simple annealing to complex, closely controlled processing procedures such as interrupted quenching. Intimately associated with proper selection of a steel is the somewhat complicated problem of specifying its heat treatment. Where the expense of heat treatment is undesirable, the problem becomes one of selecting an adequate steel of minimum cost which requires no subsequent conditioning.

In the determination of proper treatment the steel supplier can often be helpful because it is to his advantage to see that the best performance is obtained from any material furnished. Also, the experience of others in the same field which is often made available through such consultations may be of inestimable value in broadening the designers' understanding and satisfactory specification of steel treatments.

The various types of heat treatments can be divided roughly into six categories—three in the non-quenching class and three in the quenching class:

1. Stress relieving
2. Annealing
3. Normalizing
4. Case hardening (Pack, gas and liquid carburizing)
5. Surface hardening (Flame, induction, nitriding)
6. Through hardening (Water quench, oil quench,

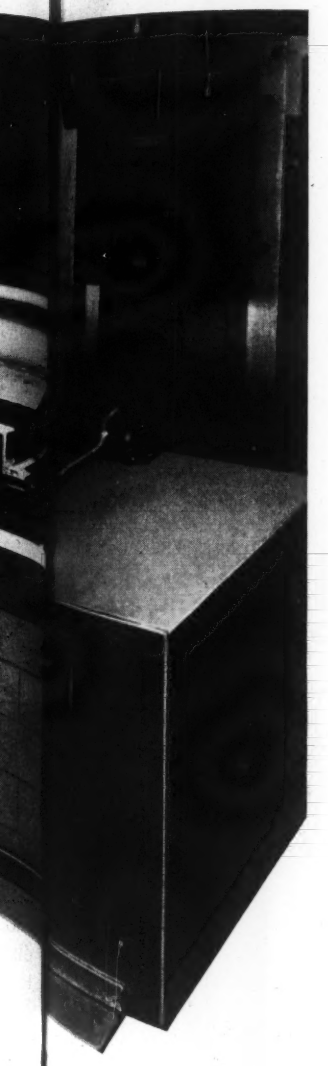
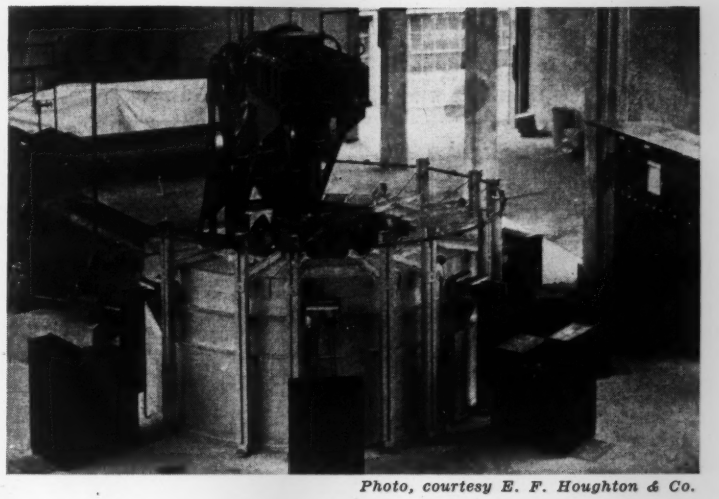


Fig. 7—Left—Battery of Upton electric salt bath furnaces capable of handling any type of heat treating work normally encountered



Photo, courtesy E. F. Houghton & Co.

Fig. 8—Right—above — Completely mechanized Ajax-Hultgren electric salt bath furnace for hardening 1000 pounds of automotive timing chain links per hour. Work is weighed, charged, passed through the 18-foot circular sodium cyanide bath in 30 seconds to attain a temperature of 1530 F, quenched, washed, and dried automatically

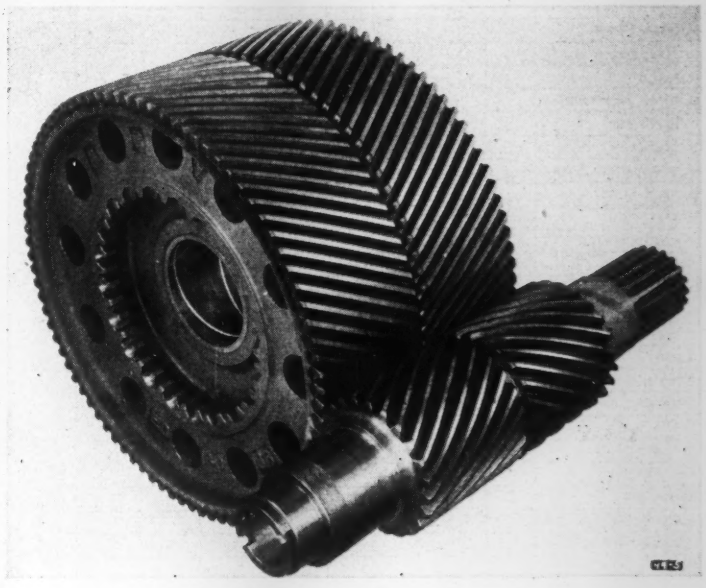


Fig. 9—Right—Gear and pinion for high-speed reversing marine drive utilize flame hardening as well as conventional heat treatment

Martempering, Austempering, isothermal treatment, subzero treatment)

Two points to keep in mind in selecting a proper heat treatment are: (1) Select the type of steel which will develop the desired physical properties, and (2) preferably select one which is readily available and from which these properties may be safely obtained with the least effort and cost taking into consideration such important items as machinability, freedom from distortion, etc., which affect the final fabrication of the part after it is heat treated. As far as cost of the heat treatment itself is concerned stress relieving, annealing and normalizing are the least expensive since they merely involve a simple heating and cooling cycle without a liquid quench.

STRESS RELIEVING: This treatment is used to relieve stresses generally induced by some form of cold work or work done under the critical point of a steel. Generally the treatment involves heating the steel to some point under the critical point (depending upon the steel and part in question) and cooling in air. It is often used to relieve straightening strains so a part can be machined without undue distortion. It is also used after machining and prior to heat treating to minimize distortion in treating, particularly where the part is of intricate design or long and slender. Considering the simplicity of the stress relieving treatment, the benefits gained in reducing processing time of the part in the shop can be very great. Usually, although not always, this treatment is used as an auxiliary or in conjunction with one of the other treatments, particularly those involving a quench.

ANNEALING: As most steel users know this is a treatment used to improve the machinability of medium and high-carbon steels (generally over 0.40 per cent carbon). The tensile strength and elastic limit are generally reduced by this treatment while at the same time the elongation and reduction of area is increased, so it is often desirable that the part subsequently should be heat treated to increase its hardness or strength or to improve its physical properties. Use of a steel in the annealed state without further treatment would generally indicate failure in obtaining the inherent physical properties of the material. It sometimes is advisable to consider another, and oftentimes lower-priced, steel that can be used

TABLE III

Steel Application and Heat Treating Guide*

Use or Part	Low-Carbon		Medium-Carbon			High-Carbon Oil High-Tool Steel Types	High-Carbon Water-Hardening Tool Steel Types
	C1020 C1117 etc.	A2315-20 3115-20 4615-20 5120 8620 etc.	C1040-50 1137 etc.	A3140-50 4140-50 5145 8640-50 8740-50 6145 9442-50 etc.	A4340 3250 etc.		
Axles	C	C	N, T, A	S, T		T	T
Arbors			N, T	T	T		
Armature Shafts			T	T	T		
Ball Races		C	S	T		T	T
Bolts & Studs			T, A	T	T		
Bushings	C	C				T	
Cams		C				T	T
Camshafts	C	C		T	T		
Cant Dogs							T
Chain Links				T			
Chain Pins, Rollers	C	C					
Chuck Jaws		C		T		T	
Chuck Screws			N, A	T			
Clutches					T	T	
Collets						T	T
Connecting Rods				T	T		
Crankshafts			N, S, A	S, T	S, T		
Drift Pins			N	T			
Engine Bolts	C	C	N, T	T			
Gears	C	C	N, S, T, A	S, T	S, T	T	
Guides, Pins						T	T
Mandrels	C	C		T		T	
Pinions	C	C	N, S, T	S, T	S, T	T	
Pins	C					T	T
Pistons		C				T	
Pumps Shafts			N, T, A	T			
Rolls	C	C	S	S, T	S, T	T	T
Lead Screws			N, A	T			
Set Screws			T	T			
Spindles	C	C	S, T, A	S, T	S, T	T	T
Stay bolts	N	A					
Thrust Washers		C				T	
Turbine Shafts			N, T, A	T			
Turnbuckles			T	T			
U-bolts			T	T			
Universal Joint Pins	C	C					
Universal Joint Bodies			N, T, A	T	T		
Worms	C	C	S, T	S, T			

* Heat treatments indicated in this table are as follows:
N = Normalized
C = Case hardened
S = Surface hardened
T = Through hardened (including interrupted quench)
A = As-rolled or natural condition.

in the "natural" or "as-rolled" state and still have physical properties similar to the annealed steel. An example of this would be the use of AISI C1137 as-rolled instead of AISI A4140 annealed where approximately the following physical properties might be expected:

		Ten. Str. (psi)	Y.P. (psi)	Elong. (% in 2 in.)	Red. Area (%)	Machinability
A4140	Ann.	90,000	53,000	30	62	55
C1137	Nat.	92,000	55,000	27	62	75

NORMALIZING: This familiar treatment commonly involves heating the steel to some point above its critical temperature and cooling in air. The two outstanding purposes for specifying normalizing are as follows:

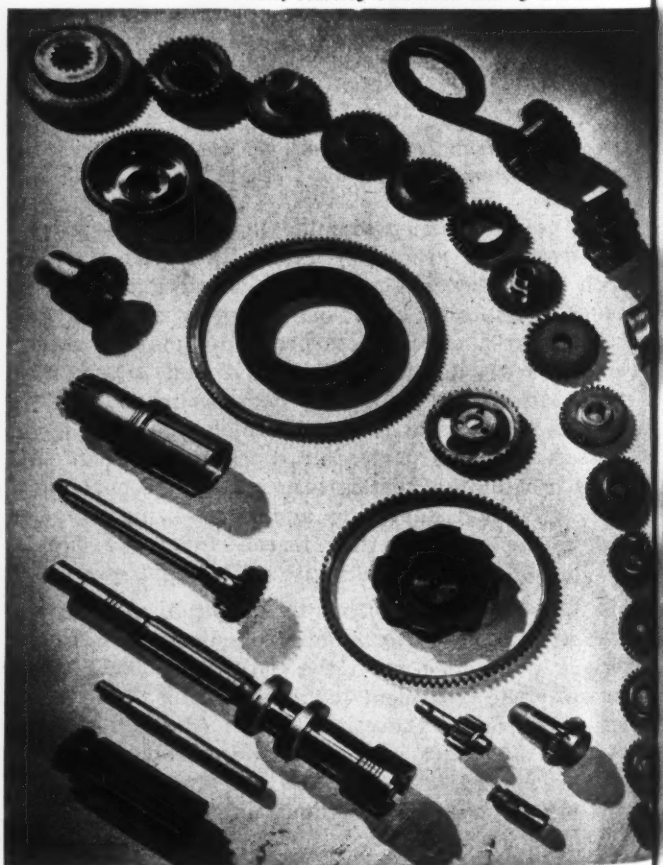
1. Stress relieving. After a part has been hammered by forging it is generally normalized to relieve the hammer stresses. Obviously this applies to all types of steels which can be forged. As in other stress relieving treatments, the purpose is to minimize distortion in subsequent machining, heat treating or service operations

2. Improving physical properties. Often the low and medium-carbon steels are normalized to relieve rolling stresses and to promote uniformity of structure; this has the effect of aiding machinability and increasing the physical properties over as-rolled stock. The extent of these effects depends upon the steel, medium-carbon grades (0.35 to 0.55 per cent carbon) being generally more responsive than the low-carbon grades (under 0.25 per cent carbon). Extremely large bars of the "heat treating" medium-carbon grades (over 10 or 12 inches in diameter and depending upon the alloying elements present in the steel) often do not respond well to regular quenching treatments because of the mass which retards the cooling. Normalizing is resorted to in such cases to get as near to the physicals desired as possible. Cost is less than for quenching and the results are often equally as good on heavy sections. Strains caused by welding are also often relieved by normalizing.

CASE HARDENING: Some machine parts such as gears, cams, bushings, roller bearings, etc., have to withstand considerable shock and abrasion in service

Fig. 10—Group of typical machine parts flame hardened in mass production

Photo, courtesy Cincinnati Milling Machine Co.



but nevertheless should be readily machinable to keep production costs down. A low-carbon steel (under 0.25 per cent carbon) is resistant to shock and is easily machined; if a high-carbon case is applied and hardened, all of the above requirements are met. Three methods are generally used in case hardening:

1. *Pack Carburizing:* While this is one of the oldest methods of carburizing, it is still one of the most widely used processes. It is adaptable for producing heavy or thin cases in both small and large parts. One advantage of this method is that the carburizing compound used in packing the pots or boxes supports the parts and also retards the cooling thus holding warpage to a minimum. A disadvantage of this process is the time and cost of packing the pots, boxes or tubes; it is also a rather dirty handling process. Case depths up to approximately 0.070-inch can be obtained.

2. *Gas Carburizing:* This process produces the desired case depth in about the same length of time as pack carburizing. The case is obtained by exposing small parts in a rotating retort to a gas, such as illuminating gas, coal or oil gases rich in carbon monoxide and in hydrocarbons which act as carburizing mediums. Sometimes a certain amount of solid carburizer is added with the work to enrich the carburizing atmosphere and to cushion the work revolving in the retort. This is a good productive method particularly on smaller parts that can be handled easily and which are not likely to damage or be damaged by the equipment when it is rotating.

3. *Liquid Carburizing and Cyaniding:* This process is used effectively for case depths generally under 0.025-inch and on parts that can be handled to advantage in salt bath equipment without mechanical aid. These liquid baths usually produce a harder and somewhat more brittle case than that offered by pack or gas carburizing because the case often contains nitrides along with the carbides. The nitrides tend to restrict the depth of hardening and develop brittleness in the case. However, certain salt solutions on the market are said to overcome some of these difficulties.

A process called "Perlitonizing" said to produce an all-carbon case up to 0.040-inch in thickness and occasionally deeper. For instance bulldozer parts are liquid carburized to depths of 0.060-inch. "Chapmanizing" is a process which gives a very tough nitrided case (tougher than that obtained by cyaniding with potassium or sodium cyanide) from 0.002-inch to 0.035-inch deep. Liquid carburizing is particularly desirable for small lots, but can be adapted for production work as required, *Fig.* 8. The fact remains that this process is primarily suited for parts on which a shallow case is satisfactory and where a rapid rate of penetration is desirable. The parts come out of the bath uniform and clean, and close control of the process is possible.

After deciding that carburizing will produce parts best suited for the job in question, i.e., capable of withstanding considerable shock and abrasive action in service and still have good machinability, the actual depth of case necessary remains to be determined. The obvious answer is "no deeper than necessary". The amount of grinding involved is a big factor in determining the depth of the case. Also, a part subject to considerable pressure or pounding should generally have a deep case (0.050 to 0.060-inch) because the lighter cases might not be strong enough and might tend to mush or break in. A typical example in the deep case class is a carburized chuck jaw. A reamer body is another application for a deep case. At this point a word of caution concerning deep cases would perhaps be timely. If a part, such as a gear which must run fast under a heavy load, develops much frictional heat during operation, a very hard (61 to 64 Rockwell C), deep case (for instance, 0.050-inch or up) may develop cracks or checks from the heat generated. This also may occur during the grinding operation. This is probably because a hard, deep case lacks flexibility and cannot "move" when expansion on the surface occurs due to the heat developed. In such instances a softer, thinner case (say 55 to 60 Rockwell C and 0.040 to 0.050-inch deep) would be less likely to check. Case depths of 0.020 to 0.040-inch are common in bevel gears, pinions, miter gears and worms.

Selective case hardening is useful in many in-

Photo, courtesy Ohio Crankshaft Co.

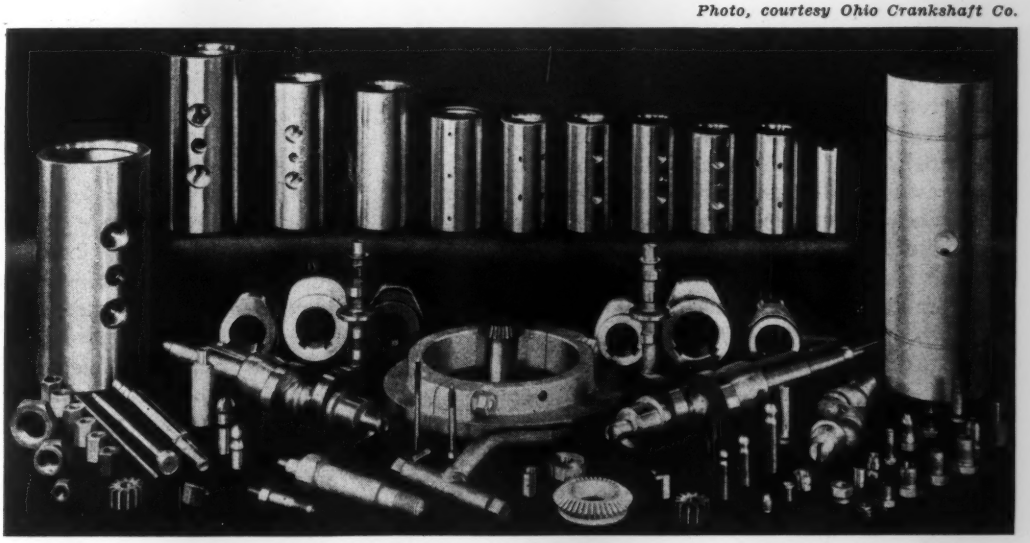


Fig. 11—Right — Representative group of machine parts production heat treated by the induction method

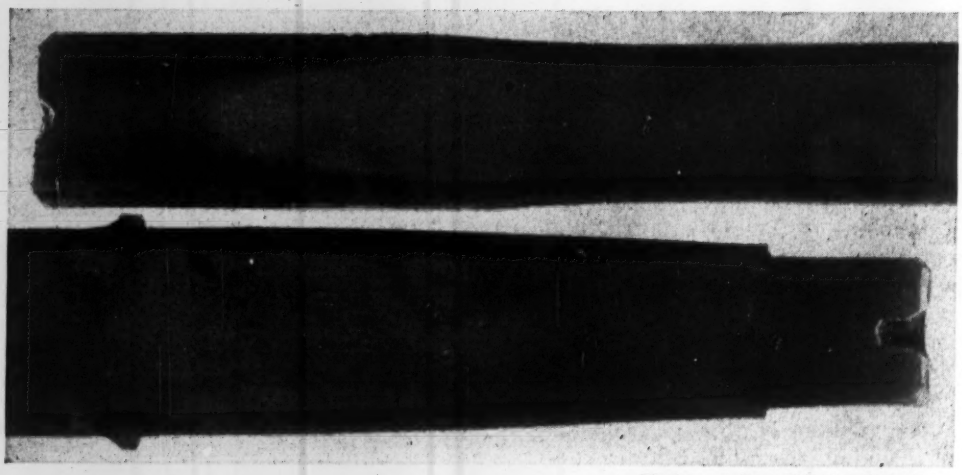


Fig. 12—Cut sections of automotive axle showing induction-hardened surface. Surface is fully hardened to Rockwell C55 to a depth of 0.125-inch

Photo, courtesy Ohio Crankshaft Co.

stances. An example might be a shaft that requires a high degree of hardness for a short distance where a bearing is located. By copper plating all except the bearing surface section and carburizing and hardening the shaft in the regular way, the bearing surface only would be hardened. The copper plating would prevent the remainder of the shaft from absorbing any additional carbon so that it will remain relatively soft. Another method would be to carburize the entire shaft and machine off the carburized surface from sections not requiring additional hardness before the hardening step of the treatment. Of course allowance would have to be made for the extra stock removed in machining.

A guide track in an extremely high-speed conveying machine presented some interesting problems. To withstand the shock and wear caused by constant high-speed service the track had to be hard and tough. Distortion had to be held to a minimum during treatment so that the sections could be straightened within grinding limits. The track was made up in sections about 4½ feet long from 1½ by 4⅝ inches AISI 4615 steel. After rough machining, each piece was pack carburized to a depth of about 0.065-inch and straightened; machine work was then completed removing the carburized steel from the nonwearing surfaces. This was done to facilitate straightening after hardening. A stress relieving treatment followed and then to further reduce distortion to a minimum the sections were Martempered instead of being quenched in oil in the customary manner. (Martempering is covered under interrupted quenches in the following.) The final steps consisted of again straightening and grinding. The finished track had a 60 Rockwell C case about 0.040-inch deep.

The average designer will probably be content to know when or when not to case harden and leave it up to the facilities at hand as to which method of case hardening to use. Not all heat treating plants have gas carburizing equipment because of the furnace expense and limited use, but most of them do have pack and liquid carburizing equipment. As far as the relation to case depth and toughness is concerned, the case thickness should not be more than one-sixth of the section thickness if toughness is to be maintained.

SURFACE HARDENING: This treatment is generally applied when a part requires a hard wearing surface combined with a stronger, harder core than can be readily developed by the use of carburizing steels. In most instances the steels used are in the 0.35 to 0.45 per cent carbon range which is high enough to produce the necessary surface hardness, as well as high tensile and yield strength below the surface. Common applications for surface hardening are heavy-duty gears, pinions, pins, and crankshafts. The two most widely used methods of surface hardening are flame and induction hardening:

Flame Hardening: This involves heating quickly by direct application of a flame to the surface of a part and quenching generally with water, although occasionally soluble oil is used. In this way a surface hardness anywhere from 50 to 65 Rockwell C may be obtianed depending upon the type of steel used and the mechanics of the treatment. If the hardener is an expert, almost any steel from the medium carbon to the high-carbon oil hardening grades may be flame hardened. However, as stated above, most flame hardening is done on steels in the 0.35 to 0.45 per cent carbon range because good results can be obtained normally either by hand or machine methods. The nature of the part determines to what, if any, extent it should be preheat treated to obtain the necessary core or body qualities. It is these body qualities that determine whether a plain carbon or an alloy steel should be used.

Combination Treatment An Answer

Reverse gear units for high-speed boats, which are subjected to extremely severe service conditions, are shown in *Fig.* 9. The gears had to withstand considerable wear and therefore a hard tooth surface was essential but, inasmuch as the tooth loading under certain conditions reached extremely high pressures, carburizing steels failed because the core was not capable of supporting the case. On the other hand, a gear machined after heat treatment (which was desirable in order to produce the most accurate tooth form) was strong enough, but did not attain the necessary hardness on the wearing surfaces. The problem was solved by using a good machining 0.50

carbon-manganese-chromium-molybdenum alloy steel for the pinions which were rough machined and then heat treated to about a 450 Brinell hardness. The rough blanks were then finish machined all over and the wearing surfaces of the gear teeth were finally flame hardened to about 55 Rockwell C. This treatment produced in the body of the gear approximately the following physical properties:

Tensile strength	225,000 psi
Elastic limit	200,000 psi
Elongation in 2 inch	12%
Reduction of area	45%
Izod impact	20 to 22 ft-lb
Wearing surface hardness	55 Rockwell C

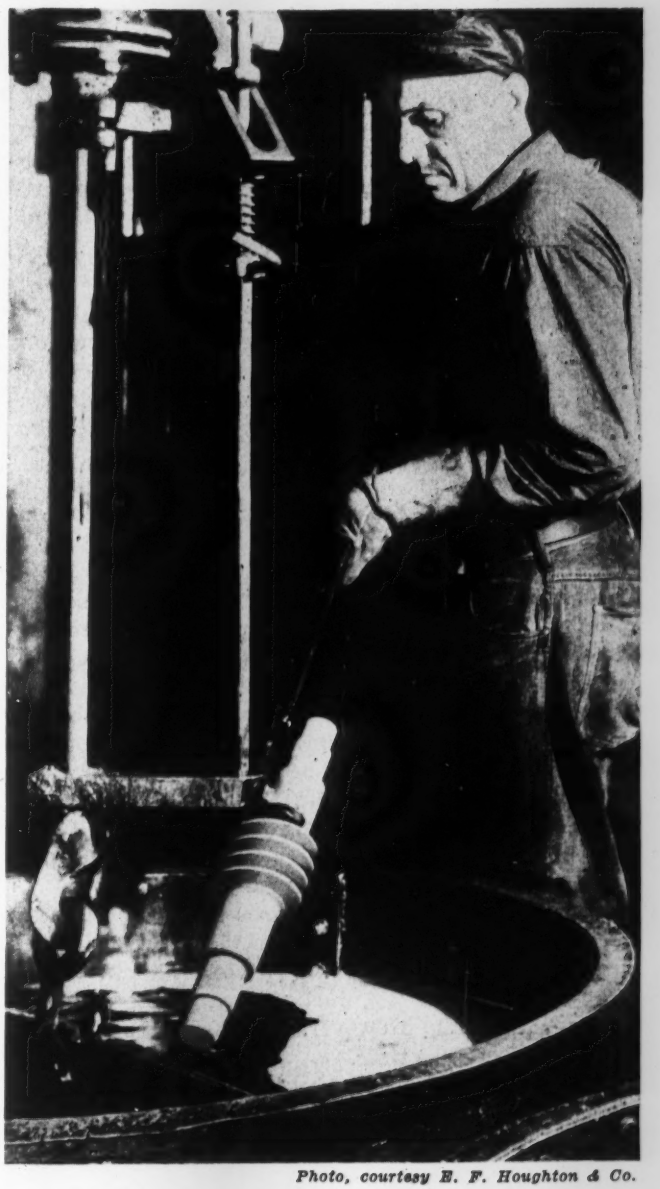
In less severe service applications the pinions were heat treated to about 300 Brinell after being turned to finished size. The gears were then completely finished after which they were flame hardened. The pinions or smaller gears in *Fig.* 9 were made of alloy-steel bar stock and the larger gears were cast from a special chromium-molybdenum steel similar to AISI A4137. On the cast gears, all machining except the cutting of the teeth was done before heat treating. After heat treating to about 280 Brinell, the teeth were completely cut and then flame hardened to about 50 Rockwell C.

Mass Production Flame Hardening

Flame hardening normally results in little distortion, particularly if parts are symmetrical in design as are gears. This treatment has been used mostly on small lots because of its adaptability and low cost. However, in recent years equipment has become available that definitely places flame hardening in the mass production class also, *Fig.* 10.

Induction Hardening: This is an extremely fast (faster than most of the flame hardening procedures), precision controlled surface hardening method particularly adaptable to production lots. The process is used on parts similar to those mentioned in flame hardening. A representative group of parts that have been induction hardened are shown in *Fig.* 11. If a variety of parts and sizes are involved, the heat inducing coils ordinarily have to be changed to suit the part being treated. Most of the machines on the market today have easily replaceable coils. Work heated and quenched by this method comes out clean with no appreciable distortion. The depth of hardening depends, as in flame hardening, upon the penetration of the applied or induced heat, the nature of the quench, etc., *Fig.* 12.

Nitriding: While this treatment is more of a case hardening treatment than surface hardening as the term is used here, it is being included in this group because application is more often in the surface hardening class than in the usual category of case hardening parts. This method is used when a very hard, abrasion resisting surface is desired. The case obtained is composed of brittle nitrides and is thin (usually from 0.010 to 0.045-inch deep). For this reason it is preferably used in connection with simple abrasive wear rather than for parts that may be subject to rough or fatiguing use. Special analysis steels



Photo, courtesy E. F. Houghton & Co.

Fig. 13—Worm gear made from oil hardening steel in the process of being quenched

under the name "Nitralloy" are the ones most commonly used for nitrided parts. Hardnesses up to 70 Rockwell C are obtainable. Many of the standard analysis alloy steels such as AISI 4145, 6145, etc., can be nitrided, but will not generally produce as hard or deep a case as Nitralloy. Parts to be nitrided are usually heat treated in the conventional manner prior to nitriding to obtain a hard, tough backing for the case that is to be applied. Often, bars or forgings from which parts are machined are preheat treated.

Technically speaking, there are two common methods of producing a case containing nitrides—one by using a cyanide salt bath which was previously mentioned under Case Hardening (generally applied to the low-carbon steels), and the other through the use of a gas which is the method generally associated with the term nitriding. The gas method involves sealing the part in a furnace and heating it in an atmosphere of ammonia gas for 60 to 90 hours depending upon the depth of case desired and the steel

used. For instance a 0.50 carbon-manganese-chromium-molybdenum steel with physical properties similar to AISI A4150 was nitrided at 950 F for 60 hours which produced a 58 to 60 Rockwell C case about 0.030-inch deep. The steel is cooled from the nitriding heat without quenching. Because there is no quenching involved there are no quenching strains developed that might cause distortion, consequently distortion in most cases is practically nil, a point that is of interest on many parts.

THROUGH HARDENING: This is the method of hardening that is most widely used. It is generally applied to medium and high-carbon steels to bring out the physical properties inherent in those steels for parts such as shafts, gears, axles, studs, etc. It is used to develop hardness and toughness, particularly where good tensile and yield strength is required, or a specific combination of hardness and toughness. A word of caution on the specifying of through hardening without due consideration of other methods is perhaps timely here.

Occasionally through hardening is specified for parts that must withstand wear and resist considerable fatigue with the thought in mind that such treatment will obtain a high, wear resistant hardness. It is true that the wear resistance will probably be satisfactory, but at the same time the high hardness throughout the part may be detrimental to fatigue resistance. Shafts, arbors, and such parts have been known to crack after varying lengths of service for this reason. In such instances a case hardened part would probably give much longer life.

Three types of heating furnaces in common use are the oven, pit and liquid bath which can be heated with gas, oil, or electricity. To some extent, in sections up to about 3½ inches, flame and induction heating are used. However, oven furnaces are used most at the present time.

In order to obtain the best results from through hardening it is of interest to the designer that the steel be treated properly. Otherwise the part may fail and he may be unjustly blamed for specifying the wrong steel or treatment. If a section is heavy, care should be taken to make sure that it is soaked through at the hardening temperature to insure full hardness and reduce any tendency to distort or crack on quenching. Also, if the atmosphere of the furnace is not right, greater than the anticipated decarburization of the surface of a part may occur. Such will affect the wearing qualities particularly if insufficient stock is removed in grinding to eliminate the decarbonized skin which will not harden properly on the quench. The tempering or drawing phase of the treatment should not be slighted; this is the step wherein the quenched part is softened or "tempered" to produce the desired physical properties. A rule-of-thumb states that a part should be held at the drawing heat one hour per inch of cross section in order to insure thorough heating. Any length of time over that arrived at by this rule will generally not affect the hardness to any serious extent, but it will sometimes tend to increase the toughness of the steel.

Mass Effect Important

An important point the designer should always keep in mind is the fact that the mass of a part has a vital effect upon the physical properties particularly when the through hardening, medium-carbon steels are involved. Occasionally a blueprint will appear covering a medium or large-size part, a shaft, for instance, where both a definite hardness and physical properties expected are specified. A checkup of the situation often reveals that both requirements cannot be met because data applicable to small sizes of the steel desired were used in arriving at the specifications for a piece of much greater mass. The tables of physical properties shown in many books are based on about ¾ or 1-inch diameter heat-treated bars and, for heavier sections, allowance should always be made for the effect of mass. In such cases it is generally better to specify either the physical properties required or else the desired hardness rather than both unless the ranges shown are sufficiently wide to take all the variables in consideration.

Liquid salt baths have of late come into wide use. In such baths the parts are heated by immersion in the liquid salt. Outside influences—such as air, that might affect the surface of the part—are eliminated, thus reducing scaling, oxidation and decarburization to a minimum.

Three types of quenching media are used in through hardening:

Water quench: This is generally used on plain carbon steels that require fast cooling to obtain top hardness. If the part is intricate or if considerable toughness is required, the oil quench should be considered.

Oil quench: This is the most widely used quench

(*Continued on Page* 190)

Photo, courtesy E. F. Houghton & Co.

Fig. 14—Large ring section being given an isothermal heat treatment to obviate distortion otherwise encountered

Co-ordinating Design and Manufacture

. . . in the development of a complex machine

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FROM inception to acceptance, the design and development of a machine as complex as a modern aircraft engine demands co-ordination of the highest degree. Paralleling the evolution of the functional design, plans must be pushed for the procurement of purchased parts and materials and for the establishment of production procedures, *Fig.* 1.

How the departments involved are kept fully informed of progress, how design modifications to suit production are put into effect, and other phases of co-ordination of a large aircraft engine manufacturing operation are discussed in this article. It is hoped that the experience reflected in these procedures will prove helpful in streamlining the co-ordination of design and manufacturing in other machinery building plants.

Control of development funds within the engineering department is accomplished by the budget and planning division, *Fig.* 2, which functions as the "business office" to assure that development objectives are accomplished within the management-approved yearly operating budget. To reduce the overall requirements into specific increments of engineering work, an engineering project authorization (EPA) is established for each major project. An EPA may cover, for example, one section of a government contract. A quarterly budget is established for each EPA commensurate with the funds available to accomplish the specific objectives of the project. This EPA defines the scope of work to be done, a schedule for each phase of such work—layout, design, detail-

Fig. 1—Top—Frequent conferences of engineering and manufacturing personnel help to iron out the wrinkles of design and production planning

ing, checking, fabrication, testing, and final report—and the appropriate funds.

The EPA is further reduced to work programs which carry accounting charge numbers in order that costs may be accumulated in detail against definite and specific portions of each EPA. One EPA may have as many as 15 to 20 work programs active under it at any given time. Different work program numbers may be assigned to the drafting, research, development, and experimental test divisions for the performance of their respective functions. Administration of the EPA's and work programs budget-wise and schedule-wise is the function of the budget and planning division, which also deals with preparation of proposals for military contracts, procurement of experimental parts and equipment, handling of asset expenditure requests (mostly experimental test, research, and materials laboratory test equipment requirements), allocation of manpower within the engineering department, maintenance of various financial ledgers, and related functions.

Within the framework of the foregoing authorization and control system, the work of the engineering department proceeds from the inception of a new design to its final release as a bill of material for production manufacturing. It is this particular phase of engineering to which attention will be directed.

Having determined the requirements to be met by his new design, the project engineer directs the layout and co-ordinates his assistants who may be specialists on the design of individual engine components such as compressors, turbines, reduction gearing, combustion chambers, controls, etc. During this early stage of design work, advance prints are made and forwarded to the production engineering division and the experimental manufacturing department to acquaint them with the scope of the work generally, in order that they may estimate their machine tool and materials requirements, and to establish tentative fabrication schedules. Also during this period, extensive contacts are made, through the purchasing department, to co-ordinate vendor requirements for specialized components such as control systems, fuel systems and other items which may require concurrent design and development outside the scope of the company's usual fabrication.

After completion of the layout design which indicates the configuration of the engine, detail drafting of the various engine sections is begun. As each component is completed, check prints are forwarded by the detail room to production engineering where they are reviewed in great detail by the process engineers to determine feasibility of manufacture. This may lead to suggested changes contributing to simplicity of the detail parts and ease of assembly, in consideration of existing tooling and facilities. Wooden mock-ups assist in developing the design of certain parts, *Fig.* 3. Frequent changes in the detail drawings result from this co-ordination.

Complicated Parts Detailed First

As each engine section is co-ordinated with production engineering, checking of the detail drawings is begun in the checking room and continues concurrently with the detailing of the balance of the engine. Every attempt is made by the project engineer to see that the most complex parts or those requiring castings, forgings or specialized tooling are detailed and checked first, whenever feasible. This permits these parts to be released first for fabrication, allowing maximum procurement time for them against the final fabrication date for the entire engine.

Assume now that the foregoing procedure is nearing completion and that portions of the engine are ready for final release for fabrication. Up to the point of release of experimental parts, design and manufacturing co-ordination has taken place through forwarding of advance prints of the layout drawings and "check prints" of the detail drawings to production engineering.

The next stage of co-ordination between engineer-

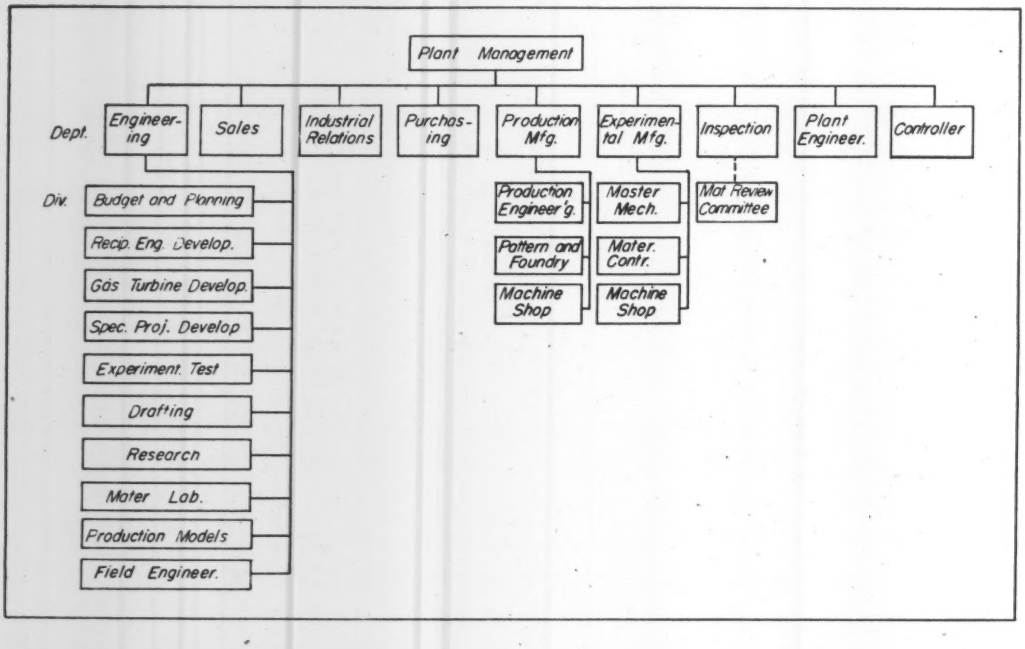

Fig. 2—Portion of organization chart, showing the departments and divisions involved in co-ordinating design and manufacturing

ing and manufacturing, while not primarily concerned with design, is of interest because it indicates the close degree of correlation and co-operation necessary to produce satisfactory experimental parts on schedule. The release procedure formally requests the experimental manufacturing department to make the parts in accordance with a certain design. It is unnecessary to go into the somewhat cumbersome system of records and paperwork required to keep track of part numbers, change letters, blueprints, copies, etc. Suffice it to say that the requisite instructions and prints, together with the work program charge number, are forwarded through the budget and planning division to the materials control division of the experimental manufacturing department. An IBM record of each release is made by the budget and planning division with a listing of all parts ordered on it. Also included is the date of release and a desired delivery date.

Fig. 3—Above—New designs in aircraft engine parts are frequently mocked up in wood before release to the experimental machine shop for fabrication

From the desired dates specified by the project engineer, together with other program information, the engineering budget and planning division and materials control set up the overall fabrication and delivery schedule covering all releases and all parts carried on the IBM listing. These schedules are then applied to the experimental machine shop and to purchasing. After scheduling, a promise date is marked after each part number on each release, and the IBM listing is broken down by work program or release number and the promise date information thus returned through the planning division to the project engineers affected. The IBM listing is republished semimonthly to add new releases, delete delivered items, and record changes in scheduling or promise dates.

The course of a part through process engineering, experimental machine shop and purchasing often requires a high degree of design coordination. After it has been determined whether a part is to be made in the shop or purchased, the design of the part plays a prominent part in the selection of a vendor. The project engineer is frequently called upon by purchasing to visit vendors to inspect their facilities and later to assist them with technical problems encountered during manufacture, especially where design changes are requested either by the project engineer or the vendor to improve the part or to facilitate fabrication.

Similarly, a part to be fabricated in the shop often requires engineering consultation during the preparation of operation sheets for the fabrication sequence, during tool design and procurement, and in relation to material selection and deviations, *Fig.* 1. Such coordination is accomplished through notification by the affected experimental manufacturing personnel to the engineering budget and planning division. The affected project engineer and planning and materials control representatives then confer, reach a decision, and proceed as agreed with necessary changes, com-

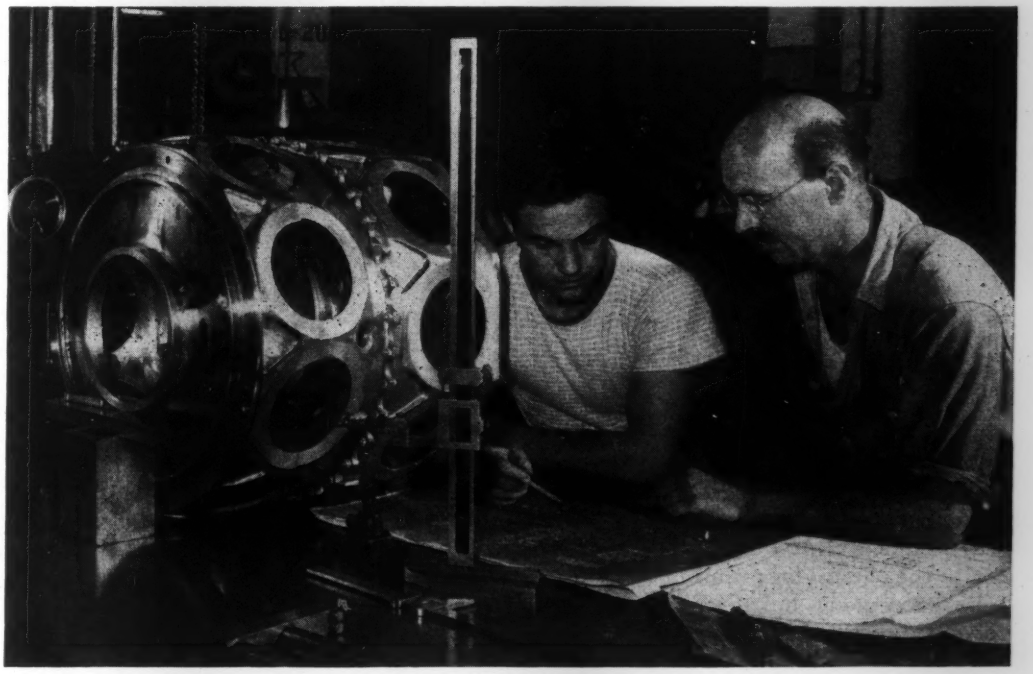

Fig. 4—Right—Dimensions of such vital parts as a forged alloy steel crankcase receive careful checking at various stages of the manufacturing process

promises, and the possible attendant rescheduling often made necessary.

During actual fabrication in the experimental machine shop, parts are followed by materials control expediters to insure that schedules are maintained in accordance with the IBM promise dates. Here again frequent engineering co-ordination is necessary. Each development engineering group—reciprocating engines, gas turbines, special projects, etc.—has a shop liaison engineer who is thoroughly familiar with shop facilities and equipment and at the same time knows the engineering objectives to be accomplished on his respective project engineers' programs. He is consantly in the shop helping to work out the "bugs" during fabrication by authorizing deviations if required or referring the shop problem back to the project engineer for possible redesign. Frequently the project engineer himself lives with a complex part in the shop in order to gain first-hand knowledge from the experimental part as to what will be feasible should the same or similar part go into production.

In addition to the foregoing co-ordination, the engineering budget and planning division maintains a procurement co-ordination section which constantly checks with materials control as to the status of urgently required parts, as well as other parts on order, and returns such information to the project engineer in the interim period between the semi-monthly IBM parts requirements listings. This group also provides certain interdepartmental expediting functions not handled by materials control, such as

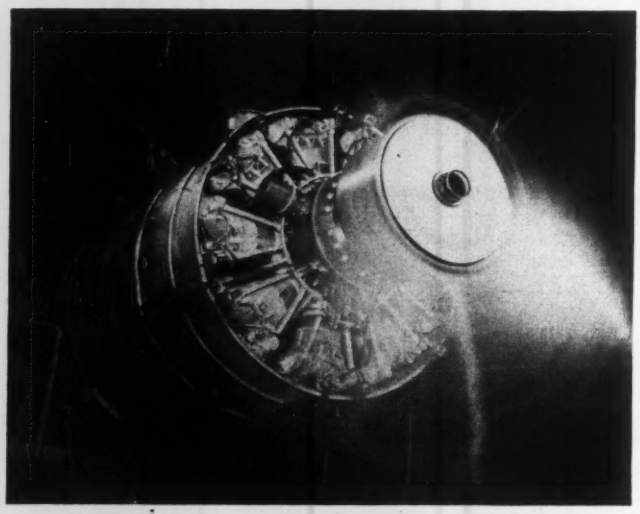

Fig. 5—Acceptance tests, which may run as long as 150 hours, are the final proof of successful engine design

transferring production finished parts associated with an experimental engine, making local emergency pick-ups of odd lots of materials or off-the-shelf items needed quickly, and similar service functions to expedite the overall program.

The foregoing has outlined the co-ordination involved in procuring experimental parts for development of a new design. The next phase of design co-ordination with manufacturing arrives when the engine is in the later stages of development and a production order is received either from the military or the airlines. Such engines are, of course, to be produced to exacting specifications, *Fig.* 4, and to a precise bill of material. Another division of the engineering department, the production models division, acts as the liaison group with the manufacturing department when a bill of material for a lot of production engines has been released.

The sales department issues a factory order for a certain quantity of engines to be built in accordance with a specific bill of material per a certain monthly schedule. Several different production engine models may be running concurrently in the production manufacturing department. During the course of such fabrication, the production models division engineers are in constant liaison with the shop at all stages of the engine building from the initial withdrawal of rough materials until the engine has passed its final acceptance test, *Fig.* 5.

When Changes Must Be Made

Whenever the design of a part must be changed to facilitate production or because additional development or service testing has indicated an improvement, the production models division issues the necessary stop order to halt work to the old drawings and initiates the change in design which replaces it with a changed or a new part. Engineering records issues the actual paperwork, changes the bill of material, recalls old blueprints, and issues prints to the new part number or change letter, etc. Such changes may originate at the request of engineering, manufacturing or the customer (sales). The production models division also provides engineering consultation, recommendations, decisions, and action as required at all stages of manufacture and test and sits on the materials review committee to pass on the acceptance of materials which may be out of blueprint limits or questionable for any other reason.

Also bearing on the co-ordination of engineering design with manufacturing are the services of the research division, materials laboratory division, and field engineering division of the engineering department. As stress and vibration analyses, development of new materials, changed operational requirements, and similar circumstances dictate, these affected divisions make recommendations to the project engineers for changes to the engine. They then work through the production models division with the production manufacturing department until their recommendations are incorporated in the processes or engines and are substantiated by testing. The correction of service difficulties often results in engine design changes which are handled as outlined.

The detail operation of the systems developed and in use to accomplish the design and manufacturing co-ordination are outside the scope of this article and must, in any case, be tailored to the cloth of the particular industry in question. The peculiarities of the aircraft engine business require that such co-ordination be conducted accurately and with dispatch and ever with regard to the safety, durability, and interchangeability of the product.

Calculating Deflection of Curved Beams

By Kenneth E. Lofgren
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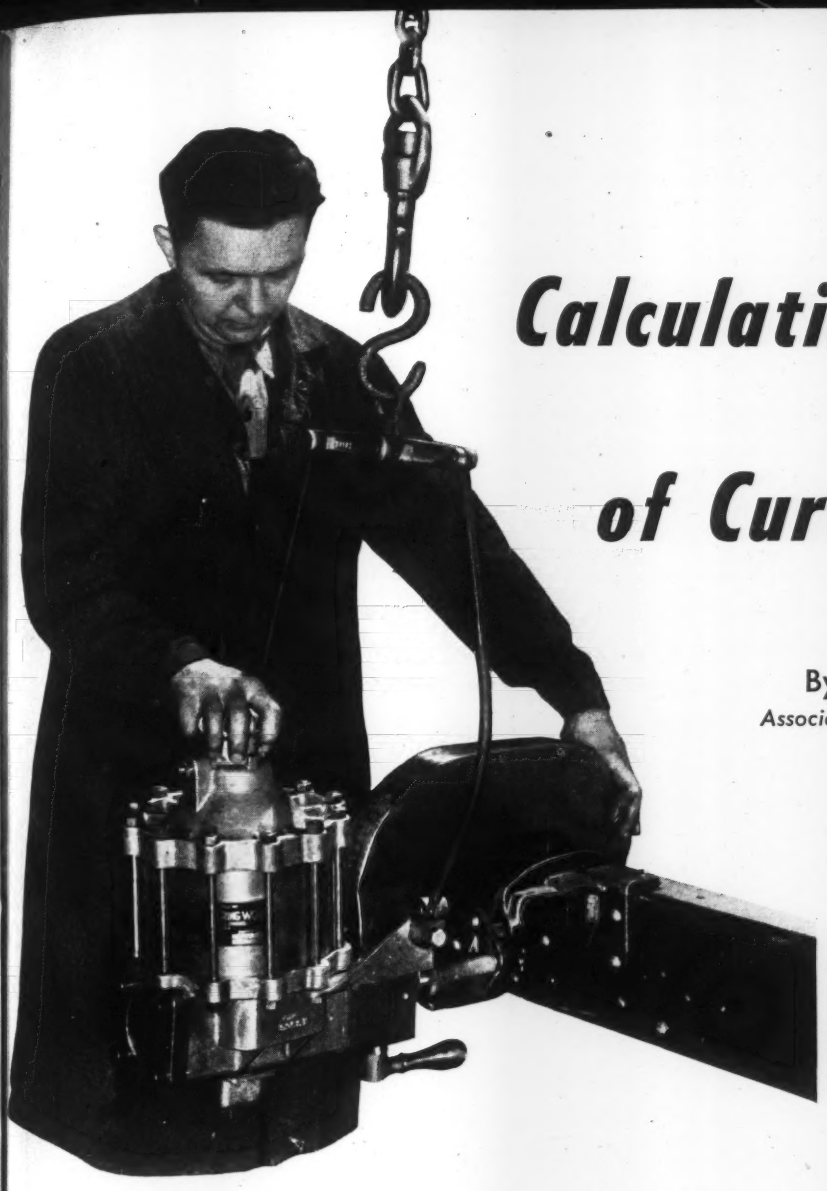


ALTHOUGH well established techniques are available for calculating the strength of curved beams, the determination of deflections is generally considered to be beyond the scope of most textbooks and handbooks. Curved beam problems are of many types. Hand riveting machines, *Fig.* 1, small welding machines, stitching machines, drill presses, and jig saws are but a few of the standard machines offering these problems.

This article discusses the problems of flexural deflection of such curved beams and presents a number of methods for their solution. The author does not claim any originality for the methods used, although he believes that some of the applications of well known principles are new.

Before beginning the detailed analysis it is important to consider briefly some thoughts about deflections in general. First, deflections in various structures and machine frames are important enough to warrant considerable study. Many machines depend on the maintaining of adequate rigidity for their satisfactory performance.

On the other hand, a sensible attitude must be adopted toward the matter of deflections. In most cases only an approximate value is needed. So much is heard today of ultraprecision measurements by various optical and electronic devices that there is a temptation to believe that every device produced by a designer is going to be so measured. Happily this is not so, and if the designer is able to design his machine so that its deflection under load is within 10 or 15 per cent of what he says it will be, he has in most cases done a sufficiently good job. It is one thing to calculate a deflection of 0.068-inch and have the actual physical result 0.074-inch; it is quite another to guess that the deflection will be a "couple of thousandths" and have it 0.074-inch.

Procedures here presented will be based on the strain energy theory and, in particular, on the application of the well known Castigliano theory. This theory states that, if an expression for the strain

Fig. 1 — Top — Portable riveting machine is typical example of a machine using a curved beam construction. Photo, courtesy Hanna Engineering Works

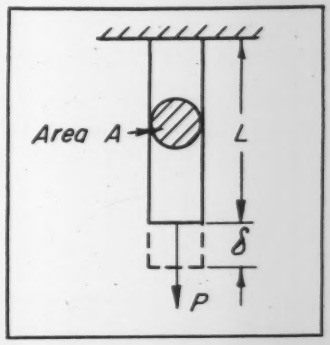


Fig. 2—Right—Rod under tension provides simple example of the application of strain energy methods

energy, U, in a member under load, P, can be found, the deflection, δ, under the load is equal to the partial derivative of the energy with respect to the load. Mathematically,

$$\delta = \frac{\partial U}{\partial P}$$

As a simple example, consider a rod under tension, *Fig.* 2. The strain energy in the rod is given by

$$U = \frac{P\delta}{2}$$

where

$$\delta = \frac{PL}{AE}$$

so

$$U = \frac{P^2L}{2AE}$$

and

$$\delta = \frac{\partial U}{\partial P} = \frac{PL}{AE}$$

This may appear as if we had merely gone around in a circle, but actually it indicates a most useful tool.

Applied to a cantilever beam, *Fig.* 3, the energy expression is developed as follows:

$$\phi = \frac{ML}{EI}$$

which is the familiar beam formula, and

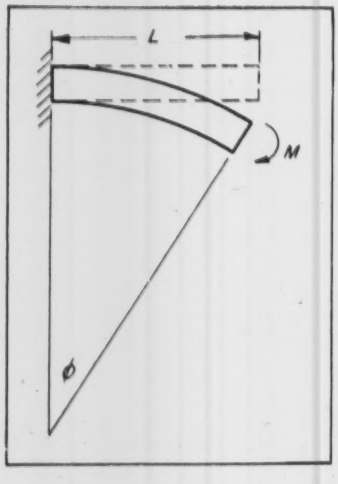
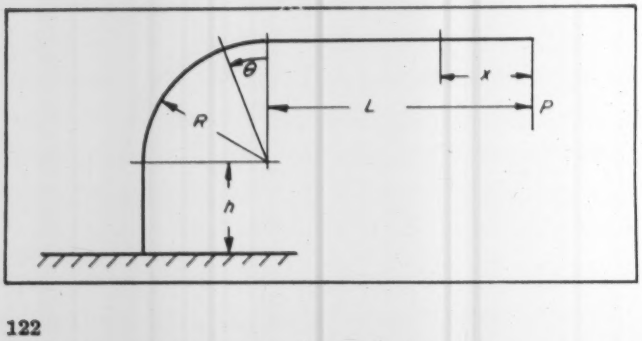


Fig. 3 — Left — Strain energy in a beam under load is half the product of the bending moment times the angle through which the moment turns

Fig. 4—Below—Example of a beam consisting of a curved portion and two straight sections. Deflection at load is determined by integrating over the three divisions



$$U = \frac{M\phi}{2}$$

therefore

$$U = \frac{M^2L}{2EI}$$

The energy per differential length ds is then

$$dU = \frac{M^2ds}{2EI}$$

and for the whole beam

$$U = \frac{1}{EI}\int_0^L \frac{M^2}{2}\,ds$$

Taking the partial derivative with respect to P,

$$\delta = \frac{1}{EI}\int_0^L M\,\frac{\partial M}{\partial P}\,ds$$

The foregoing assumes a uniform cross section. Rewriting it for a varying cross section,

$$\delta = \frac{1}{E}\int_0^L \frac{M}{I_x}\,\frac{\partial M}{\partial P}\,ds \qquad (1)$$

This can now be applied to a curved beam as shown in *Fig.* 4. A uniform cross section is assumed, and the deflections will be integrated over the three divisions of the beam. First, over the length L,

Fig. 5 — Right — Deflection of curved link may be approximated by graphically integrating along the neutral axis

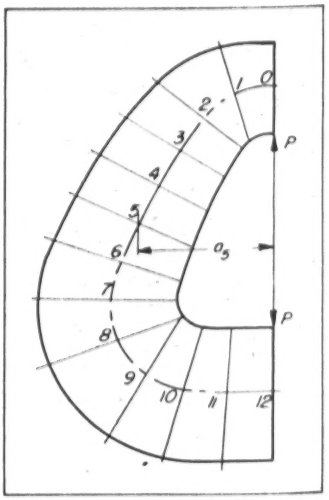
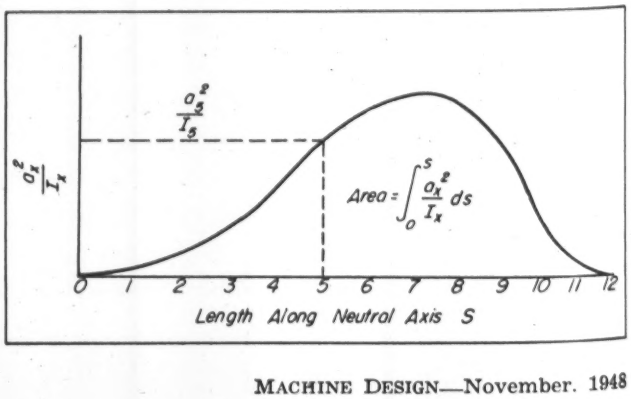


Fig. 6 — Below — Curve plotted from data obtained from Fig. 5. Area is proportional to deflection under load



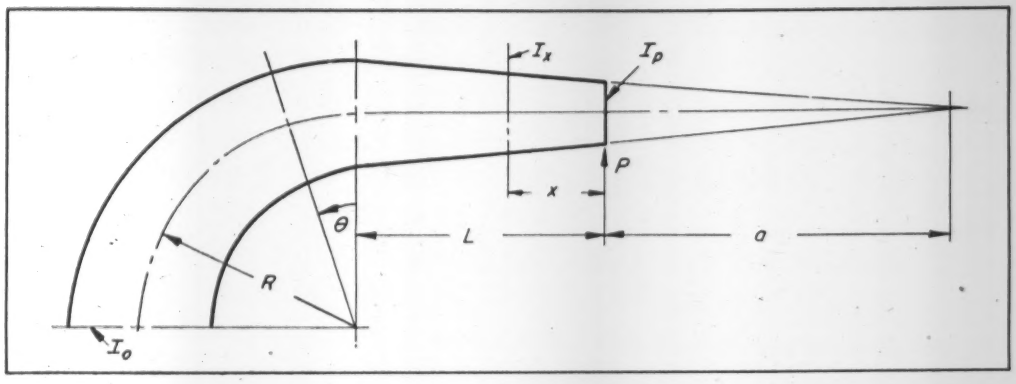


Fig. 7—Curved beam of varying cross section, with straight section, represents a fairly common type of problem occurring in machines

$$M = Px\ ;\ \frac{\partial M}{\partial P} = x\ ;\ ds = dx$$

consequently

$$\delta_1 = \frac{1}{EI}\int_0^L Px^2 dx = \frac{PL^3}{3EI}$$

Second, over the curved portion,

$$M = P(L + R\sin\theta)$$
$$\frac{\partial M}{\partial P} = L + R\sin\theta$$
$$ds = R\,d\theta$$

and

$$\delta_2 = \frac{P}{EI}\int_0^{\pi/2} R(L + R\sin\theta)^2 d\theta$$
$$= \frac{PR}{EI}\left[\frac{\pi L^2}{2} + \frac{\pi R^2}{4} + 2LR\right]$$

Finally, over the vertical portion,

$$M = P(L + R)$$
$$\frac{\partial M}{\partial P} = L + R$$
$$ds = dh$$
$$\delta_3 = \frac{1}{EI}\int_0^h P(L + R)^2\, dh = \frac{Ph}{EI}(L + R)^2$$

Then for the whole beam

$$\delta_T = \delta_1 + \delta_2 + \delta_3$$
$$= \frac{P}{EI}\left\{\frac{L^3}{3} + R\left[\frac{\pi L^2}{2} + \frac{\pi R^2}{4} + 2LR\right] + h(L + R)^2\right\} \quad \ldots\ldots (2)$$

A number of remarks must be made regarding the application of Equation 2. It has already been stated that the cross section should be uniform. However, mention must be made of the difference between the neutral axis of the section and its gravity axis. Theoretically, the neutral axis should be used in the computations. As is well known, over the curved portion of the beam the neutral axis is at a smaller radius than is the gravity axis, the distance between the two axes being a function of the radius and the size and shape of the section. Usually this distance is quite small and not much error is introduced by working with the more easily obtained gravity axis.

Another explanation may be helpful in connection with relationships between δ_1, δ_2 and δ_3. All of these deflections are under the load P. Thus δ_2 is the contribution of the curved portion of the beam to the deflection at the end of the beam under the point of application of the load.

NONUNIFORM SECTIONS: The problem of deflections is greatly complicated by sections which are not uniform. In fact, in many cases a mathematical approach is just about impossible. If an attempt is made to solve analytically a problem involving such a beam by use of Equation 1, it will be noted immediately that it must be possible to write an expression for I_x in terms of s. This is an almost impossible task in many cases. Many frames are so complicated by lateral ribs, mounting pads, special bosses and other irregularities that an expression as indicated in the foregoing is out of the question if exactness is required. The skillful designer can, however, make approximations which may satisfy practical needs. Such a scheme will be discussed later in the article and a series of curves presented which can be used without much difficulty to find the deflection of a wide variety of cases.

First, however, a semigraphical method will be presented, which is quite simple and extremely useful. A typical problem is shown in *Fig.* 5. The moments of inertia of a series of right sections are first calculated. These sections should be perpendicular to the neutral axis. This is, of course, troublesome because the neutral axis cannot be found without having the section centroid first. However, an exercise in good judgment is indicated and should result in a set of values which will give fair results. Equation 1 can be written in the following form

$$\delta = \frac{P}{E}\int_0^s \frac{a_x^2}{I_x} ds$$

where, in *Fig.* 5, a_x = moment arm from line of action of load to neutral axis of any section, and s = length along curved neutral axis, i.e., length through points 0, 1, 2, 3, 4, etc.

Plotting graphically the values of a_x^2/I_x against s,

the curve shown in *Fig.* 6 results. The a_x^2/I_x values are obtained from the layout in *Fig.* 5. Each section (such as No. 5) will have a moment of inertia (I_5) and a moment arm (a_5). The length s will be the distance along the neutral axis curve to the particular section being plotted. Thus the base line of the complete curve in *Fig.* 6 will be as long as the curve through the neutral axes. This base line is in effect a stretch-out line.

The area under the curve, *Fig.* 6, is obviously

$$\int_0^s \frac{a_x^2}{I_x}\,ds$$

and can be measured by means of a planimeter.* Multiplying by P/E will give the deflection.

A familiar type of problem which lends itself nicely to a solution by means of a series of curves is illustrated in *Fig.* 7. Prepared by the author, the curves are presented in this article, *Figs.* 8 and 9. The mathematical analysis will be given although the large amount of computation work is omitted.

As stated previously, the analytical solution requires an expression for I_x in terms of s, *Fig.* 7. Such an expression for most actual designs is practically impossible. However, a relationship which will yield quite satisfactory results is given by the following:

$$\frac{I_o}{I_x} = \frac{(a+L+R)^2}{(a+x)^2} \qquad (4)$$

Since there are so many possible proportions between I_o, I_p, R and L, it seems desirable to work through ratios of these various values. In all cases the simplifying assumption will be made that Equation 4 holds. From this it follows that the length a is defined. To illustrate this best, it will be assumed that $I_o/I_p = 9$. Then

$$\frac{I_o}{I_p} = \frac{(a+L+R)^2}{a^2} = 9$$

Now let it be further assumed that ratio $L/R = 2$. Then

$$\frac{a+L+R}{a} = 3 \quad \text{and} \quad a = 1.5\,R$$

Now Equation 1 may be applied to each portion of *Fig.* 7 as was done previously to *Fig.* 4. Taking the horizontal portion first,

$$\delta_1 = \frac{1}{E}\int_o^L \frac{M}{I_x}\,\frac{\partial M}{\partial P}\,ds$$

where

$$M = Px\,;\ \frac{\partial M}{\partial P} = x\,;\ ds = dx\,;\ I_x = I_o\frac{(a+x)^2}{(a+L+R)^2}$$

so

$$\delta_1 = \frac{P(a+L+R)^2}{EI_o}\int_o^L \frac{x^2dx}{(a+x)^2}$$

This integrates into

* A simple arithmetical summation method is shown in the illustrative example and TABLE I at the end of this article.

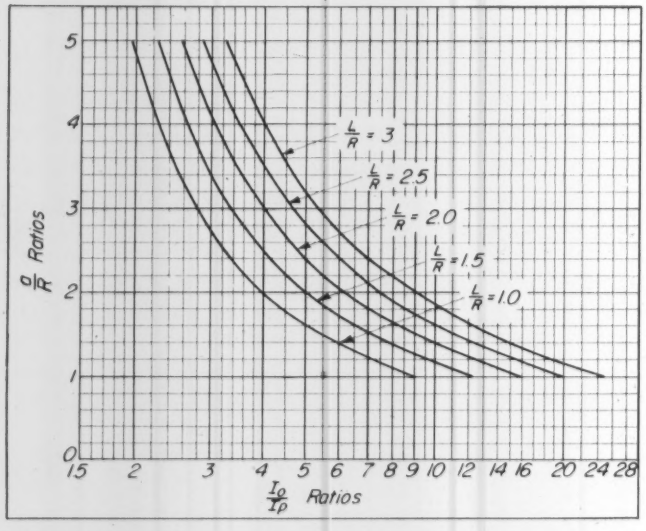


Fig. 8—Above—Chart for determining a/R ratio applicable to a curved beam of the type shown in Fig. 7

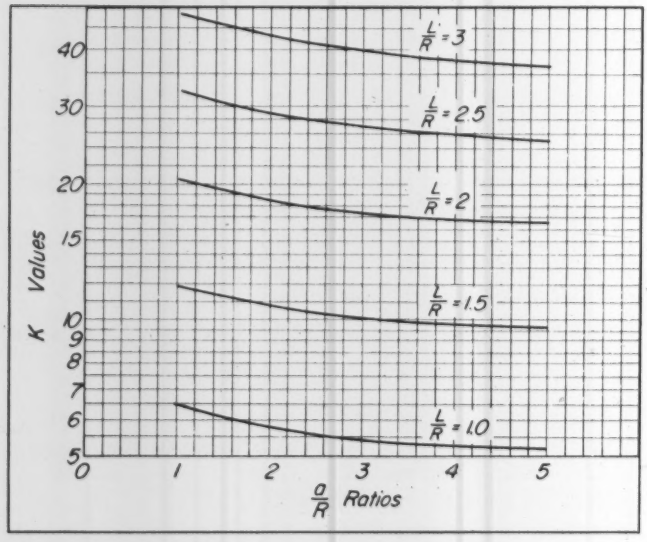


Fig. 9—Left — Chart for determining value of K to be used in Equation 5 for total deflection at the load of beam shown in Fig. 7

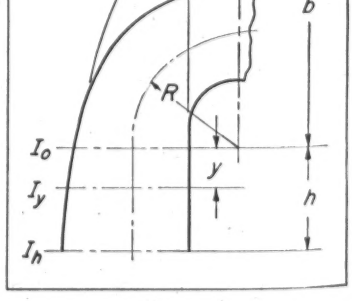


Fig. 10—Right—Basis for calculating deflection due to the deformation of the straight vertical length of the beam shown in Fig. 4, where the cross section is variable

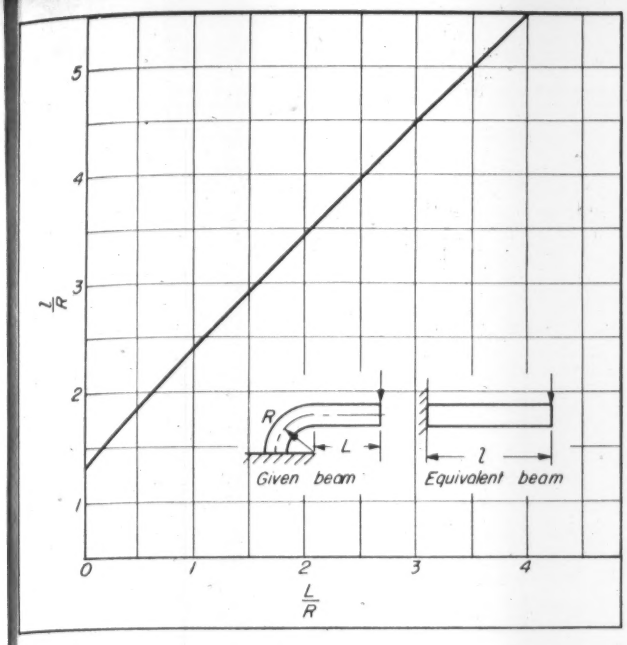


Fig. 11—Left—Chart for determining length (l) of equivalent straight beam, given length (L) and radius (R) of curved beam

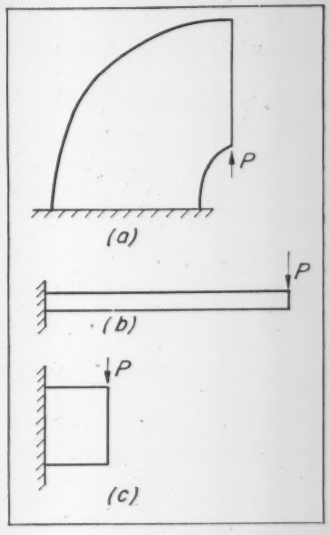
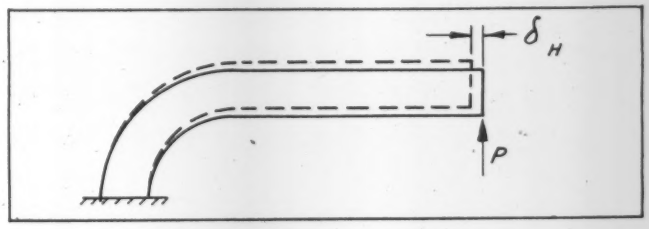


Fig. 12—Right—Illustrating proportions of beams for which shear deflections are (a and c) and are not (b) significant

Fig. 13—Below—Deflections in a direction at right angles to the load in general are of little consequence



$$\delta_1 = \frac{P(a+L+R)^2}{EI_o}\left[L + 2a\log_e\frac{a}{a+L} - \frac{a^2}{a+L} + a\right]$$

Substituting $L/R = 2$ and $a/R = 1.5$,

$$\delta_1 = 6.38\frac{PR^3}{EI_o}$$

For the curved portion

$$\delta_2 = \frac{PR}{EI_o}(a+L+R)^2\int_o^{\pi/2}\frac{(L+R\sin\theta)^2 d\theta}{(a+L+R\sin\theta)^2}$$

After some manipulation this integrates into

$$\delta_2 = 12.9\frac{PR^3}{EI_o}$$

Hence for the beam illustrated in *Fig.* 7,

$$\delta_T = \delta_1 + \delta_2 = 19.3\frac{PR^3}{EI_o} = K\frac{PR^3}{EI_o} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

A series of curves with various I_o/I_p and L/R ratios is presented in *Fig.* 8. By use of these curves a fairly accurate idea of the deflection of many complex curved beams may be found quite readily. In using these curves the value of a/R is first found from *Fig.* 8 for whatever values of I_o/I_p and L/R are desired, then from *Fig.* 9 the values of K are obtained for the corresponding a/R and L/R ratios. The sample solution given later in this article will illustrate the use of the curves.

Obviously the variation of I with h is likely to be anything, although the designer can make it what he chooses. To present a usable method, let it be assumed that

$$\frac{I_y}{I_o} = \frac{(b+y)^2}{b^2}$$

where b, y, and I_y are defined in *Fig.* 10. Then

$$\delta_3 = \frac{Pb^2(R+L)^2}{I_oE}\int_o^h \frac{dy}{(b+y)^2}$$

or

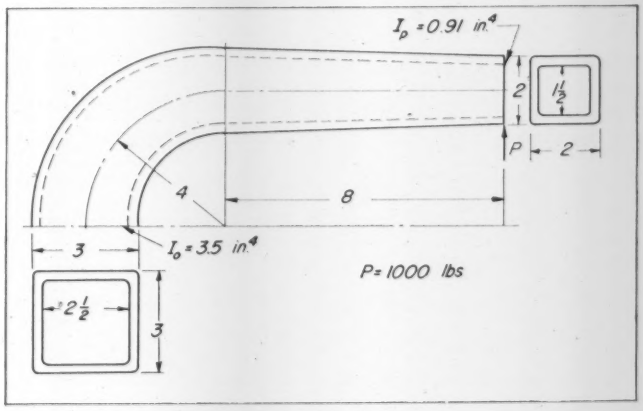
$$\delta_3 = \frac{Pbh\,(R+L)^2}{I_oE\,(b+h)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

To solve this equation it remains merely to evaluate b, which is a simple function of I_o and I_h.

EQUIVALENT BEAMS: A method which the author will call Equivalent Beams may be used to find the deflections where the cross section is complex. This method makes use of the regular and well known method of finding the deflection of a complex beam by strictly graphical means.

There does not seem to be any convenient way of employing the usual graphical solution (conjugate

Fig. 14—Proportions of a cast iron curved beam which illustrates the methods of calculation discussed



beam method) to a curved beam problem directly. An approach to this problem can be made, however, in the following manner.

The beam illustrated in *Fig.* 4, neglecting the vertical portion, will serve as an example. For the horizontal and curved portions the deflection, from Equation 2, is given by

$$\delta = \frac{P}{IE}\left\{\frac{L^3}{3} + R\left(\frac{\pi L^2}{2} + 2LR + \frac{\pi R^2}{4}\right)\right\} \quad \ldots\ldots\ldots (7)$$

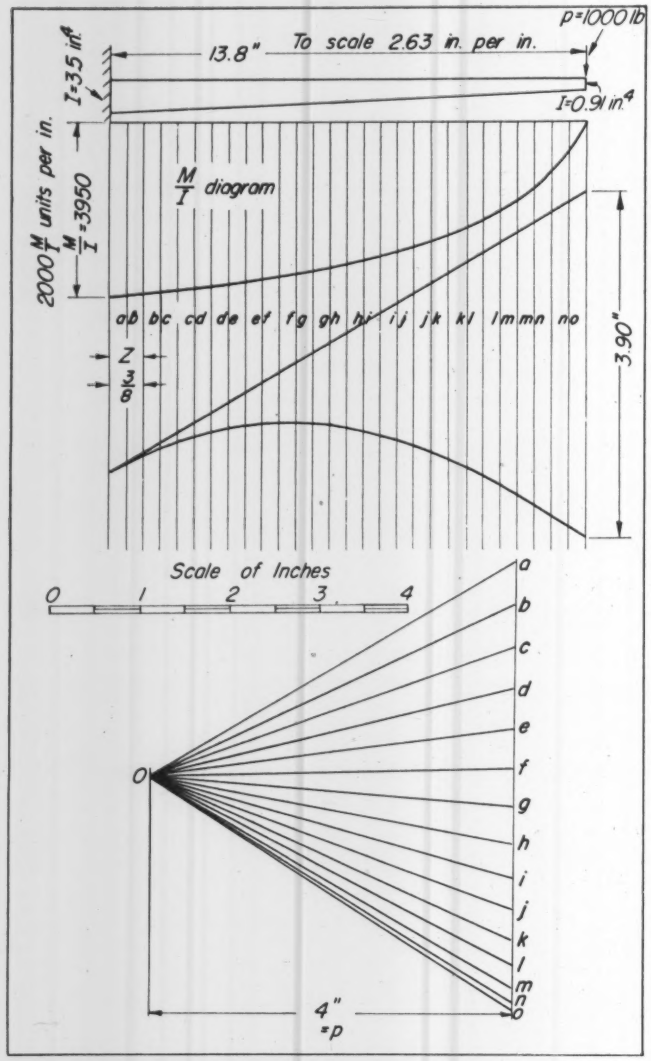
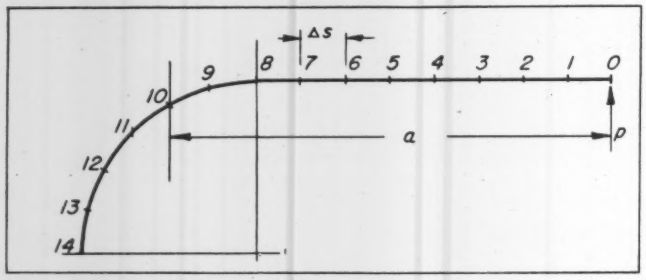

P=1000 lb
13.8" To scale 2.63 in. per in.
I=.35 in.⁴
I=0.91 in.⁴
2000 M/I units per in.
M/I =3950
M/I diagram
ab bc cd de ef fg gh hi ij jk kl lm mn no
Z
3/8
3.90"
Scale of Inches
0 1 2 3 4
a b c d e f g h i j k l m n o
4"
=p

Fig. 15—Above—Equivalent beam solution. Beam of Fig. 14 is replaced by straight beam shown at top

Fig. 16—Below—Centroidal axis of beam in Fig. 14 showing numbered stations corresponding to column 1 in Table I



The deflection for a simple cantilever beam with a load on its end is

$$\delta = \frac{Pl^3}{3EI}$$

Equating these and solving for an equivalent length of straight cantilever beam,

$$l^3 = L^3 + 3R\left\{\frac{\pi L^2}{2} + 2LR + \frac{\pi R^2}{4}\right\} \quad \ldots\ldots\ldots (8)$$

For convenience, L can be written in terms of R and the graph in *Fig.* 11 plotted. This curve is so close to a straight line over the range of interest that it can be assumed that

$$l = 1.08\,L + 1.33\,R \quad \ldots\ldots\ldots (9)$$

Thus, given a curved beam of uniform section where $R = 6$ in. and $L = 9$ in., the equivalent length of a straight cantilever beam is found by solving for l. Then $l = 1.08 \times 9 + 1.33 \times 6 = 17.7$ in., and the deflection under the load is

$$\delta = \frac{PL^3}{3EI} = \frac{P}{3EI}(17.7)^3$$

In the application of this procedure to more complex problems such as *Fig.* 7, an equivalent length of beam in terms of R could be found and a graphical determination of the deflection made which, while not exact, would be close enough for practical purposes. However, since the scheme involves a radius of curvature to the neutral axis, no attempt should be made to apply it to the type of beam illustrated in *Fig.* 5.

OTHER CONSIDERATIONS: The deflection of curved beams is influenced by two factors which have not been mentioned — shear and lateral deflections. Neither of these is likely to affect the reliability of computed results as outlined in the foregoing. However, some comments should be made about them so that the problem can be viewed with understanding.

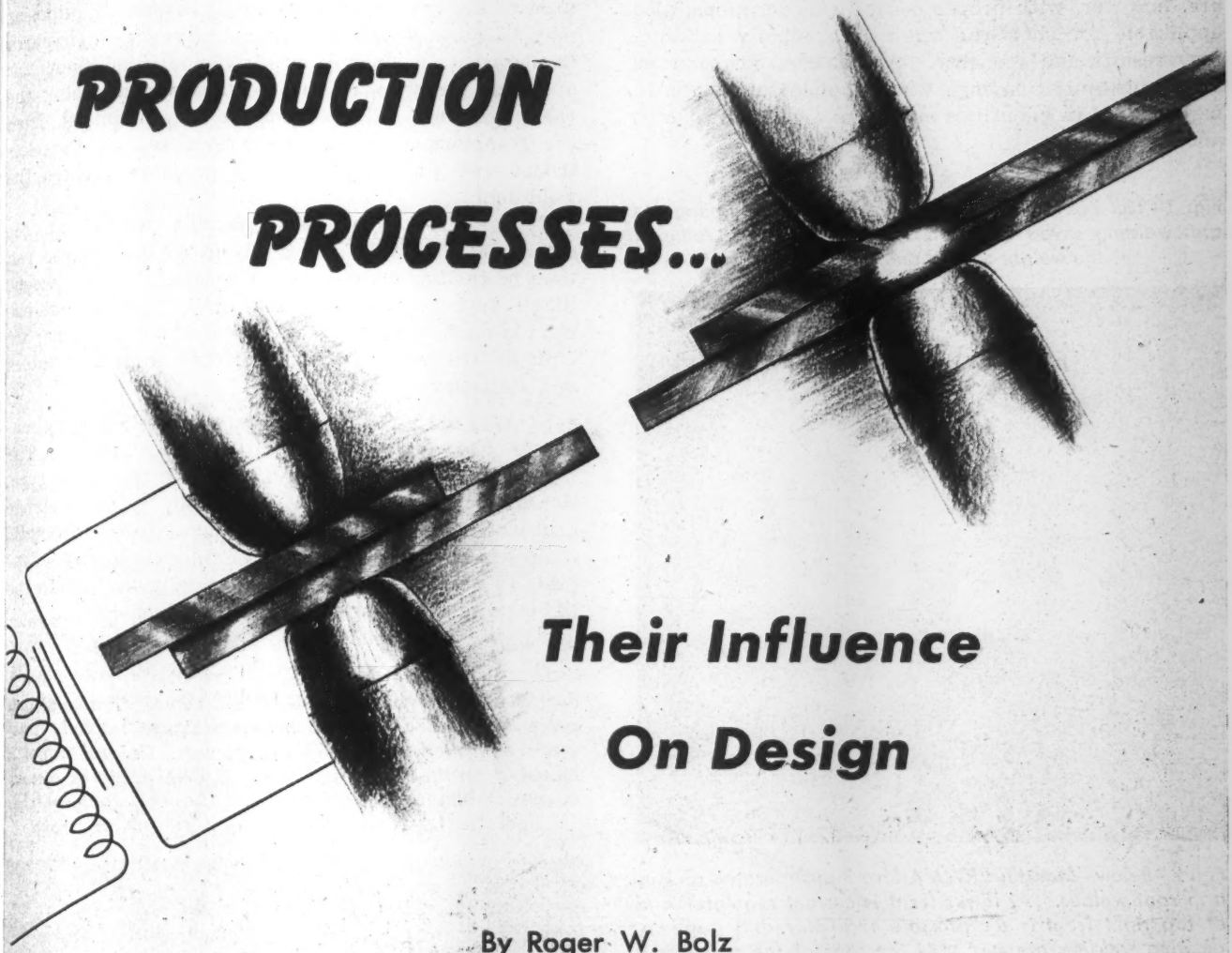
In *Fig.* 12*a* is illustrated a beam in which shear deflection might account for 20 to 30 per cent of the total deflection. Here the cross section of the beam is very large compared with the length of the beam. The same holds true for the cantilever illustrated in *Fig.* 12*c*. In *Fig.* 12*b* the proportion of shear deflection to the flexural deflection is negligible, while in *Fig.* 12*c* it might be an appreciable value up to about 30 per cent. Unless the moment arm is small with respect to the size of the cross section, it is not worth while to include a calculation of shear deflection.

In this connection, it is interesting to note that some designers will go to considerable trouble to extend their deformation computations to three and four significant figures, all the while using $E = 30{,}000{,}000$ psi and $G = 12{,}000{,}000$ psi when the true value for these quantities may be considerably different.

In the matter of lateral deflections at right angles

(*Continued on Page* 186)

PRODUCTION PROCESSES...



Their Influence On Design

By Roger W. Bolz
Associate Editor, Machine Design

Part XXXVIII–Spot Welding

AMONG the metal fabricating processes which comprise the joining of several parts by means of welding, one of the simplest and most economical is resistance welding. In resistance welding processes the fusing temperature is generated solely through the resistance offered by the parts to be welded to the passage of an electric current. Differing from other methods of welding in that no additional material is required in the welding operation, resistance welding methods utilize the application of mechanical pressure to forge the electrically heated portions together. Effect of the pressure is to refine grain structure and produce a weld with physical properties equal in most cases to the parent metal and occasionally superior.

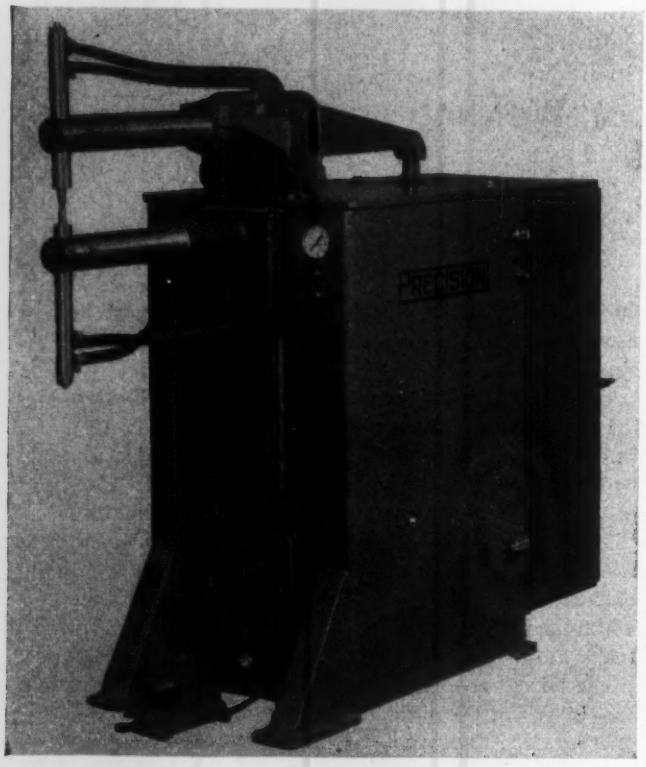
Generally, resistance welding can be divided into four principal types or classifications: (1) Spot welding, (2) seam welding, (3) projection welding, and (4) butt or flash welding. Certain of these processes may be subdivided and these subdivisions will be discussed under each specific classification.

The major characteristic of all resistance welding processes is high speed of operation. Individual welds are made in seconds or fractions of a second. Thus, these methods are

ideally suited for large-quantity production. They are, however, with proper design considerations, also applicable for short-run work with equally satisfactory results and economy. Actual cost comparisons show substantial savings when applied to designs to be produced in quantities as low as a thousand pieces and less, *Fig.* 1.

Fig. 1—Tail boom for the Northrop P-61. Redesigning for spot welding saved 200 man-hours per ship and reduced the weight of the boom by 3 pounds

Fig. 2—Below—Standard RWMA Size 3 air-operated rocker-arm spot welder. At lower front is current regulator and at top right front is air pressure regulator and gage indicating welding pressure. At the rear of the machine is shown the automatic sequencing control

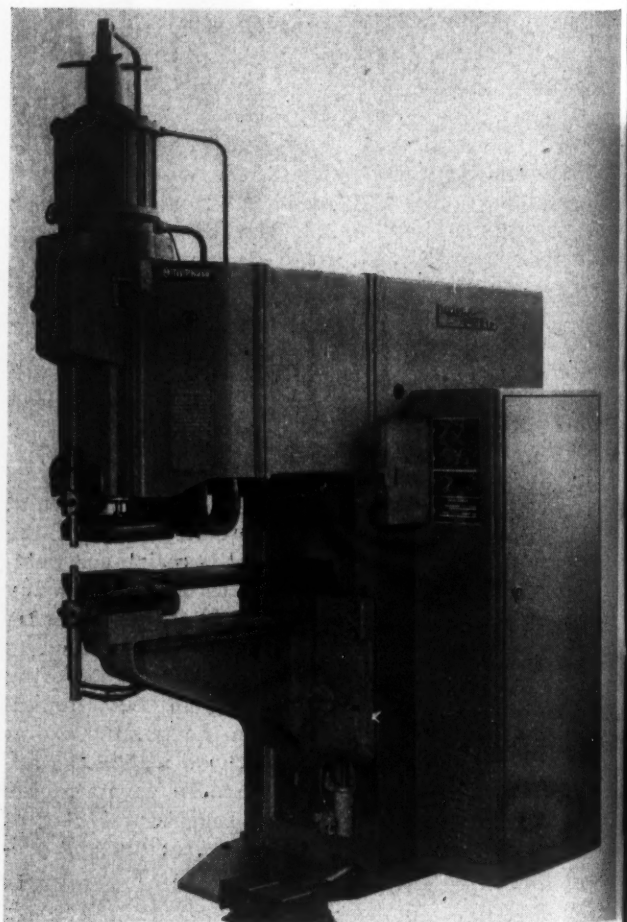


In all probability spot welding is the most widely used of the resistance welding processes. Equipment may be quite simple and inexpensive; a single-phase transformer, a pair of electrodes and a means for applying pressure to the electrodes comprising the basic machine. High current at low potential, from the transformer secondary, is localized by the electrodes and under the applied pressure creates the weld spot.

Types of spot welds can be readily divided into the categories of single and multiple welds. These can then be further divided into direct and indirect welds. Single type spot welding machines, wherein but one weld is made during one operation of the machine, are built in two general types—portable or gun machines and stationary or pedestal.

STATIONARY SINGLE-SPOT WELDERS: Stationary machines are available in two general styles: The **rocker-arm** or **walking beam** type and the **press** type. Rocker-arm machines have a rocking upper electrode arm which is actuated by foot, air or fully automatic motor-driven cam action. The machines are adaptable to a wide range of work, usually limited to the lighter gages, and seldom exceed 50 kva, *Fig.* 2.

Fig. 3—Below—Typical RWMA Size 3 combination spot and projection welder. This machine is designed for fully automatic operation on three-phase power. Control panel is mounted on the right-hand side. Special features include a retractable, adjustable stroke. The two foot switches operate the welding stroke and retraction stroke



Over 50 kva the machines are normally of the press type which carry the upper electrode in a slide, *Fig.* 3. These machines are available in sizes for welding medium up to the heaviest gage metals that can be handled. Press type welders are air operated, hydraulically operated or motor driven, hydraulic operation usually being used for the larger sizes and capacities.

Standard spot welders have been classified and standardized by the Resistance Welder Manufacturers Association into specific sizes, kva ratings and throat depths, as shown in TABLE I.

PORTABLE SINGLE-SPOT WELDERS: Where the work is too bulky to take to the welding machines, portable machines are usually used. These permit the rapid assembly of a few or a great many parts held in a fixture, *Fig.* 4. Portability, however, is limited; heavy bulky cables connect the gun to the transformer and these cables must be as short as possible, not over 10 feet and preferably less than six. Portable welders or guns are of widely varying designs and are built to accommodate an equally wide variety of designs for low, moderate and mass-production quantities of parts.

Portable guns can be classified as **pinch** guns, **expansion** guns and **bar** or **lever** type guns. Pinch guns are made with one stationary jaw and one movable jaw in the following styles: (1) Common *C* type; (2) revolving jaw gun similar to the *C* type, except one or both jaws can be revolved to permit positioning clearance; (3) scissors or rocker-arm type; (4) clam-shell type, similar to the scissors gun except

TABLE I

Specifications For Standard Welders

Rocker-Arm Spot Welders

Size No.	Rating (kva)	Throat Depth (in).
1	15	12–18–24
2	30	12–24–30
3	50	12–24–36

Press-Type Spot Welders

Size No.	Rating (kva)	Throat Depth (in).
1	50–75	18–24–36
2	100–150	18–24–36
3	150–250	18–24–36
4	300–400–500	18–24–36

that both jaws open wide to permit positioning over a wide section; and (5) universal type, a special scissors gun which permits 360-degree rotation of the gun proper on the horizontal axis and about 170 degrees on the vertical axis.

Expansion welding guns, primarily for use with welding fixtures, are of two types: Short-circuit and single-cable guns. The short-circuit gun merely conducts current from the upper electrode of a fixture to the lower electrode of the fixture in which the work is located, both electrodes being connected to the transformer secondary. These guns are made to suit the work and are either air or hydraulically operated. Single-cable guns are similar in operation to the short-circuit type except that the lower electrode is energized. The other side of the transformer secondary is connected to the gun by means of the single cable.

Bar or lever type guns are for use with fixture work and may be manually, pneumatically or hy-

Fig. 4—Portable gun spot welding 16-gage steel stampings in a special jig

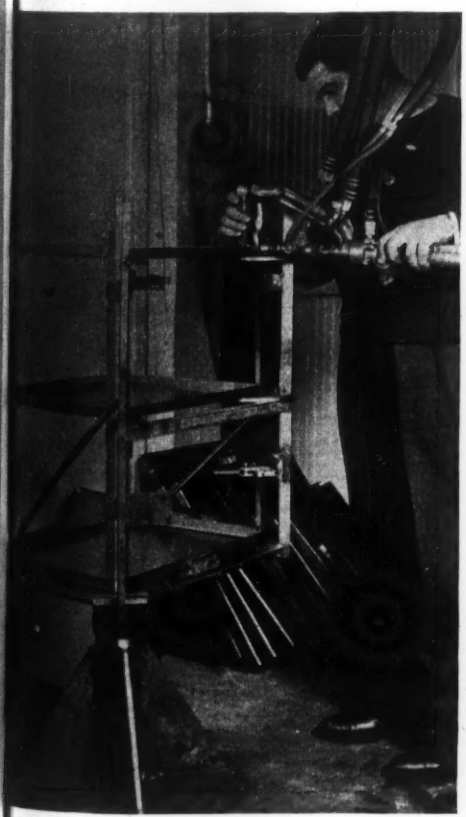
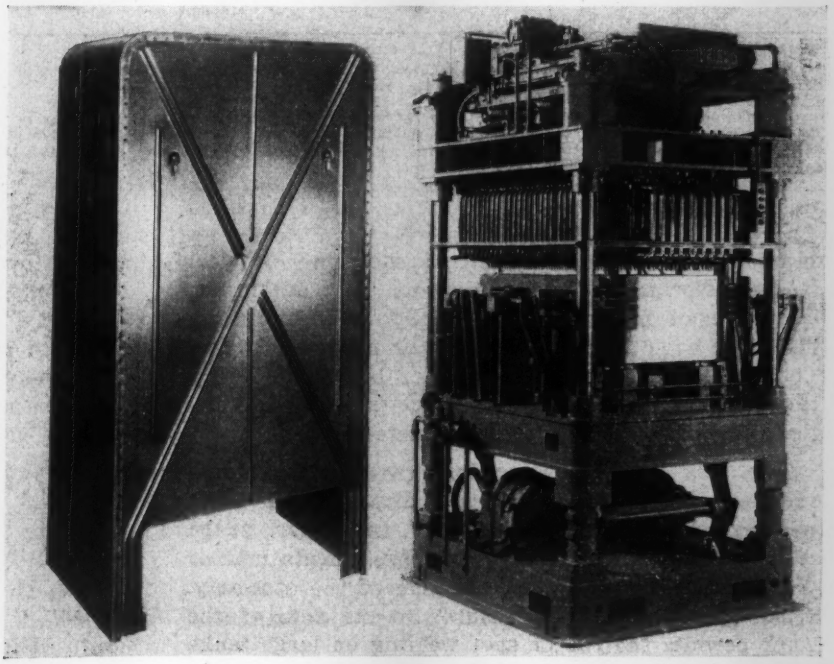


Fig. 5—Pneumatic ultra speed multiple-gun welder for welding back panels to outer shells of refrigerator cabinets, left, at the rate of 100 cabinets per hour, with 120 spots per cabinet. The machine contains three transformers with double series weld circuits making four welds per transformer. The guns are sequenced by means of a geneva-motion operated sequencing valve. The work is loaded in a convenient position, then the lower platen of the machine elevates to welding position



draulically operated. The workpiece is positioned on a stationary fixture electrode which is connected to the transformer secondary. The other side of the transformer is connected to a copper-alloy bar which encircles the fixture. Of the short-circuit type, the gun is merely inserted between the bar and the work. With the point of the gun properly positioned, pressure may be applied manually or otherwise and the welding cycle started by pressing a switch on the gun.

MULTIPLE-SPOT WELDERS: Two or more pairs of electrodes cannot properly distribute current to each weld unless some means for insuring equal distribution is used. Although two or four spots are often produced by means of a series arrangement on a single circuit, *Fig.* 5, multiple spots are normally accomplished in these machines by means of a separate secondary transformer circuit to each pair of electrodes. Normally custom-built and fully automatic, multiple-spot machines are usually quite expensive and may have from two to 100 or more electrodes. The tremendous savings possible, however, justify such special machines where large-quantity production of standard parts is contemplated, *Fig.* 6.

TYPES OF WELDS: Special types of spot welding processes are known as series, indirect and invisible welding. In series welding, *Fig.* 7, two welds can be made at once without any markings, indentations or discoloration appearing on one side of the assembly. Welding with all the pressure on one side of the work permits the use of spot welding on large tanks and bodies where otherwise an unduly long throat would be necessary. Space between welds must be at least 2 inches on the lightest gages and up to 6 or 8 inches on the heavier gages.

Indirect welding, *Fig.* 8, is used on parts which prevent proper passage of the current due to design. Invisible welds are specially controlled so as to obviate all effects of heat and shrinkage. In some cases the electrode produces a bulge which is subsequently dressed off and in others indirect introduction of the current is used to distribute current in the one part and minimize markings.

The range of spot welding applications is extremely wide and can be used for parts made from foils as thin as 0.001-inch, such as in electronic tube elements, to those made from thicker sections such as required in the machine-tool, automobile, aviation, appliance, and similar machine building industries. On materials of low conductivity—less than 20 per cent of standard copper—use of pulsation welding is preferable where gage is greater than ⅛ to 3/32-inch. With this feature which involves repeated application of welding power under maintained electrode pressure, electrode life is brought into the practical range and welding of parts such as 1-inch to 1-inch, ½-inch to 2½-inch, a 1½-inch piece between two 1-inch pieces, or a ½-inch piece to a piece any thickness up to 4 inches, is made practicable. Single impulse welding is usually considered limited to spot welding of gages up to ⅛-inch.

TABLE II*

Single-Impulse Welding Low-Carbon Steel[1]

Data Common To All Classes of Spot Welds					Setup for Best-Quality, Class A Welds					Setup for Medium-Quality, Class B Welds					Setup for Good-Quality, Class C Welds				
Thickness of Work Pieces	Electrode[2] Min. D	Electrode[2] Max. d	Min. Weld Sp.[3] c/l to c/l	Min. Overlap L	Weld Time	Electrode Force	Welding Current	Nugget Dia.	Av. Ten. Shear Str. ± 14%	Weld Time	Electrode Force	Welding Current	Nugget Dia.	Av. Ten. Shear Str. ± 17%	Weld Time	Electrode Force	Welding Current	Nugget Dia.	Av. Ten. Shear Str. ± 20%
(in.)	(in.)	(in.)	(in.)	(in.)	(c)[4]	(lb)	(amp)	(in.)	(lb)	(c)[4]	(lb)	(amp)	(in.)	(lb)	(c)[4]	(lb)	(amp)	(in.)	(lb)
0.010	⅜	⅛	¼	⅜	4	200	4000	0.13	235	5	130	3700	0.12	200	15	65	3000	0.11	160
0.021	⅜	3/16	⅜	7/16	6	300	6100	0.17	530	10	200	5100	0.16	460	22	100	3800	0.14	390
0.031	⅜	3/16	½	7/16	8	400	8000	0.21	980	15	275	6300	0.20	850	29	135	4700	0.18	790
0.040	½	¼	⅝	½	10	500	9200	0.23	1350	21	360	7500	0.22	1230	38	180	5600	0.21	1180
0.050	½	¼	⅞	9/16	12	650	10300	0.25	1820	24	410	8000	0.23	1700	42	205	6100	0.22	1600
0.062	½	¼	1 1/16	⅝	14	800	11600	0.27	2350	29	500	9000	0.26	2150	48	250	6800	0.25	2050
0.078	⅝	5/16	1⅛	11/16	21	1100	13300	0.31	3225	36	650	10400	0.30	3025	58	325	7900	0.28	2900
0.094	⅝	5/16	1⅝	¾	25	1300	14700	0.34	4100	44	790	11400	0.33	3900	66	390	8800	0.31	3750
0.109	⅝	⅜	1 13/16	13/16	29	1600	16100	0.37	5300	50	960	12200	0.36	5050	72	480	9500	0.35	4850
0.125	⅝	⅜	2	⅞	30	1800	17500	0.40	6900	60	1140	12900	0.39	6500	78	570	10000	0.37	6150

* Courtesy Taylor-Winfield Corp.

[1] Low-carbon steel is hot rolled, pickled, and lightly oiled with an ultimate strength of 42,000 to 45,000 psi similar to SAE 1005—SAE 1010. Surface of steel lightly oiled but free from grease, scale or dirt.

[2] Electrode material is RWMA Class 2 alloy.

[3] Minimum weld spacing is that distance for which no increase in welding current is necessary to compensate for the shunted current effect of adjacent welds. Spot spacing to be used as a guide only. Spacing should be determined according to stress requirements. Greater spacings should be used whenever allowed by structural considerations. When spotwelding sheets of unequal thickness, the thinner sheet determines the edge distance, spot spacings, strength, etc.

[4] Weld time is given in cycles.

Fig. 6—Right—Multiple-transformer spot welder for welding the header that goes over the door of an automobile. Both right and left-hand headers are welded on this special machine

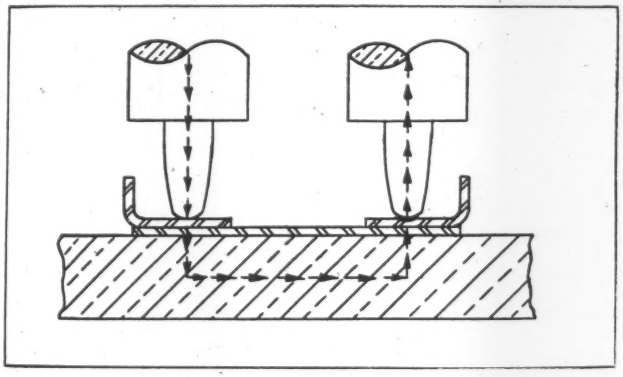


Fig. 7—Above—Assembly showing series-welded joint

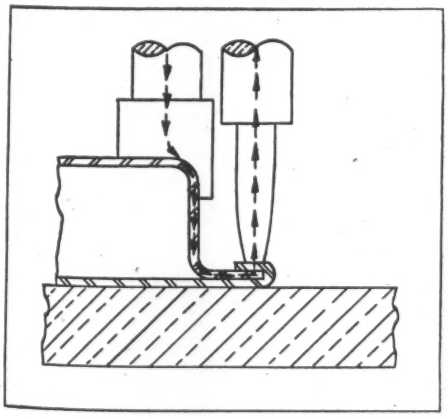


Fig. 8—Spot-welded assembly showing a typical joint design for an indirect weld

DESIGN: Differences between good and poor design of parts for resistance welding are often so small as to appear trivial, but to obtain good welds and also obtain maximum economy, proper design practices must be closely followed. Careful consideration of all environmental conditions should be made before final selection of one specific resistance welding method.

Heavy materials require a great amount of heat and power and as a rule can be fabricated best by arc or gas welding. Resistance welding, therefore, can be applied most advantageously to thin-metal fabrication. One of the primary advantages of resistance welding is speed and thus assemblies should be designed so as to permit use of as simple a machine as possible. It is specially important to avoid the necessity for intricate current carrying members in the welder which complicate feeding parts into the machine. Design should always contemplate use of the simplest possible welding electrodes.

In no case should a part be changed from one method of assembly to spot welding merely by a switch in processes. The entire design should be reviewed to assure proper proportions for the joints and adequate accessibility. This is specially true if

TABLE III

Weldability Ratings of Various Metals*

Metal	Rating
Low-Carbon Steel (SAE 1010)	A-100
Stainless Steel (18-8)	B-75
Aluminum (2S)	C-250
Aluminum (52S)	C-300
Magnesium (Dow "M")	B-290
Magnesium (Dow "J")	B-230
Nickel	B-130
Nickel Alloys (Monel, etc.)	B-65
Nickel Silver (30% Ni)	B-125
Nickel Silver (10% Ni)	B-100
Copper	F-350
Silver	F-350
Red Brass (80% Cu)	E-150
Yellow Brass (65% Cu)	C-150
Phosphor Bronze (95% Cu)	C-120
Silicon Bronze (up to 3% Si)	B-80
Aluminum Bronze (8% Al)	C-80

* A=excellent, B=good, C=fair, D=poor, E=extremely poor, and F=impractical.

joint strength is of importance. Strength of individual spots can be readily obtained and multiple-spot joints can be computed provided spot spacing meets minimum requirements. Pertinent factors regarding spot welds in SAE 1010 low-carbon steel, the most readily welded material, are shown in TABLE II. In certain cases it is necessary to develop a joint strength closely approximating that of the parent metal sheet. To accomplish this, additional rows of spots can be used until the sum of the spot diameters equals the width of the sheet. Recommended spacings must be used and intermediate rows are usually staggered. Unless spots are spaced far enough apart, welding current will shunt through previous spots and produce weak welds. Minimum spot spacing for aluminum and magnesium is usually considered as equal to 8 times the gage, 16 times being preferable.

Welding electrode tip size directly affects the size and consequently shear strength of a weld, and proper tip area is a function of material gage. A satisfactory formula for determining the electrode tip diameter for thin sheets is $d = 0.1 + 2t$ where t is the material thickness, and $d = \sqrt{t}$ for thick material. Then for every sheet thickness with its proper weld nugget there is a minimum distance which is required from the edge of the weld nugget to the edge of the part. Proper overlap of joints, *Fig.* 9, is given in TABLE II along with the other pertinent information. Too small an overlap not only produces a poor and sometimes weak joint, but often necessitates special and more costly electrodes and such joints should be modified if at all possible to conform with minimum acceptable standards. Minimum distance from the spot centerline to the edge of the sheet in aluminum or magnesium is 4 times gage, 6 times being preferred.

Proper joint design is often the key to economical and satisfactory spot welded assemblies. In *Fig.* 10 joint (*a*) shows a typical lap which can be produced on any machine. Flange joint (*b*) is also easily accessible. Should flange (*b*) be turned in, difficulty may be encountered in getting the work into and out of the machine, particularly if the leg is high. In such cases, a special machine is often required. Joint (*c*) is sometimes encountered and normally is undesirable. With sufficient room for the upper electrode, however, it can generally be made with a portable gun. Joint (*d*) is often used but should be avoided. A considerable portion of the current passes through the outer sheet and fails to pass through the joint. Flanged stamping spot-welded to a tube, shown at (*e*), can be made if the tube is sufficiently strong to resist collapse. For best results the sleeve should make a slip fit.

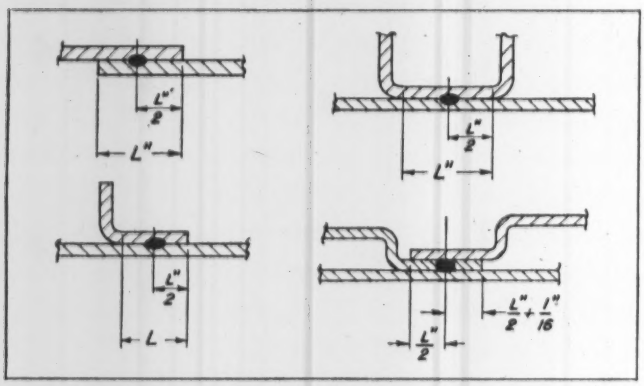


Fig. 9—Above—Sketch of parts showing overlap and spot spacings for various types of joints

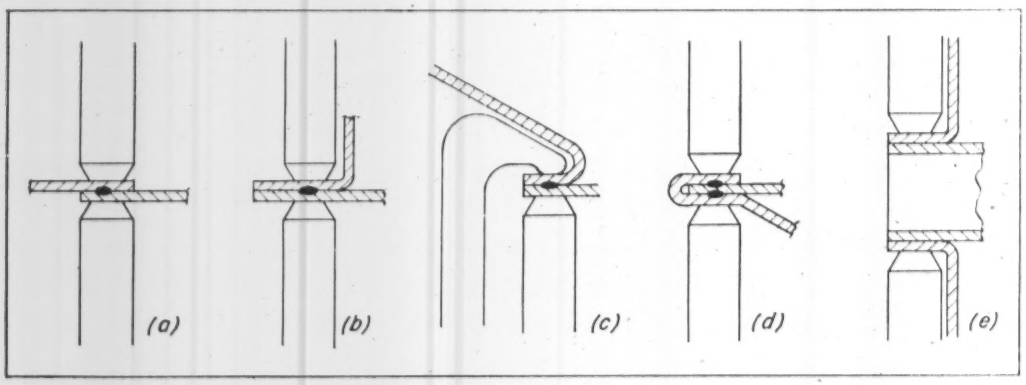


Fig. 10 — Left — Typical spot-welded joints

Fig. 11—Below — Chart of joints showing good and poor practices in regard to accessibility

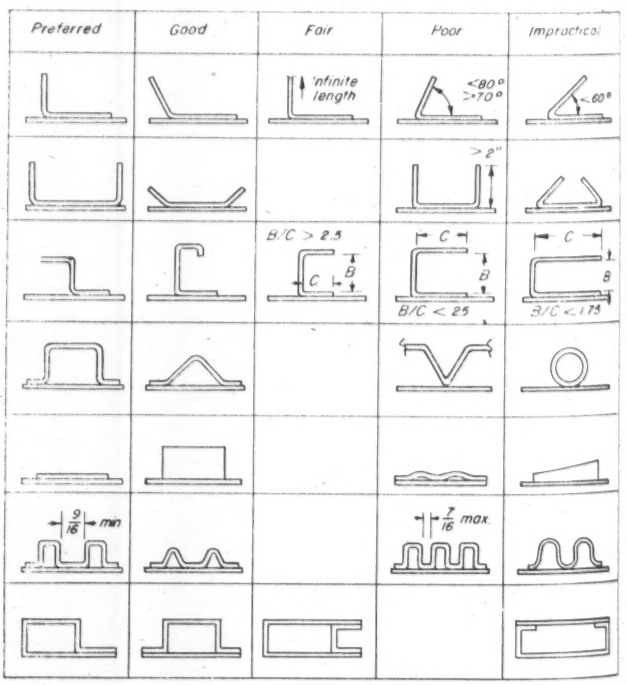


TABLE IV

Metal Combinations That Can Be Spot Welded*

METALS	Aluminum	Stainless Steel	Brass	Copper	Galvanized Iron	Steel	Lead	Monel	Nickel	Nichrome	Tin Plate	Zinc	Phos. Bronze	Nickel Silver	Terneplate
Aluminum	B	E	D	E	C	D	E	D	D	D	C	C	C	F	C
Stainless Steel	F	A	E	E	B	A	F	C	C	C	B	F	D	D	B
Brass	D	E	C	D	D	D	F	C	C	C	D	E	C	C	D
Copper	E	E	D	F	E	E	E	D	D	D	E	E	C	C	E
Galvanized Iron	C	B	D	E	B	B	D	C	C	C	B	C	D	E	B
Steel	D	A	D	E	B	A	E	C	C	C	B	F	C	D	A
Lead	E	F	F	E	D	E	C	E	E	E		C	E	E	D
Monel	D	C	C	D	C	C	E	A	B	B	C	F	C	B	C
Nickel	D	C	C	D	C	C	E	B	A	B	C	F	C	B	C
Nichrome	D	C	C	D	C	C	E	B	B	A	C	F	D	B	C
Tin Plate	C	B	D	E	B	B		C	C	C	C	C	D	D	C
Zinc	C	F	E	E	C	F	C	F	F	F	C	C	D	F	C
Phos. Bronze	C	D	C	C	D	C	E	C	C	D	D	D	B	B	D
Nickel Silver	F	D	C	C	E	D	E	B	B	B	D	F	B	A	D
Terneplate	C	B	D	E	B	A	D	C	C	C	C	C	C	D	B

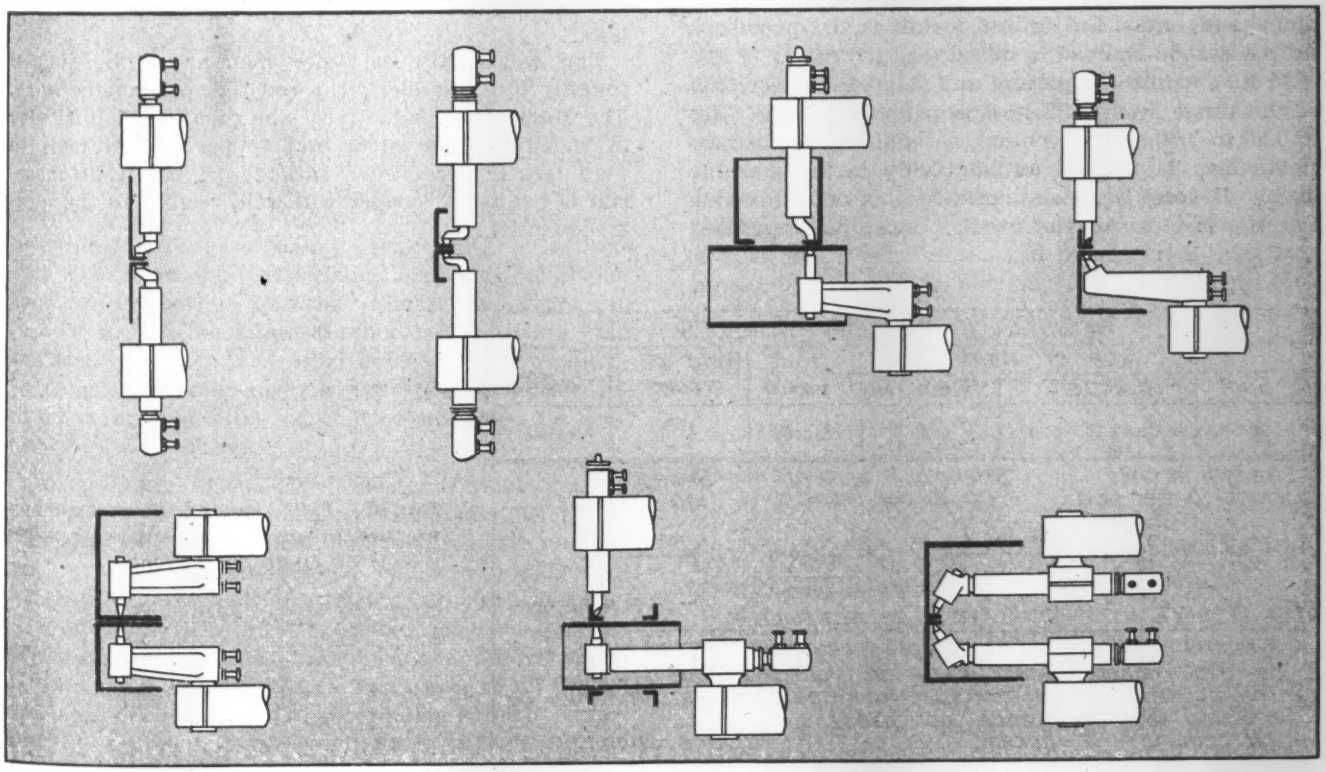
* A—excellent, B—good, C—fair, D—poor, E—very poor, and F—impractical.

Good and poor design practices in regard to adequate accessibility are shown in *Fig.* 11. From these sketches an idea as to simplifying joint assembly and achieving maximum production economy can be gained. Typical standard electrode tips and operations are shown in *Fig.* 12.

It is not important that two pieces to be welded have the same thickness. A piece of 16-gage sheet will weld to a 6-inch plate as readily as to another 16-gage sheet. Multiple thicknesses of low-carbon or corrosion-resistant steels may be spot welded together subject to a number of restrictions enumerated in the following:

1. When all sheets are of equal gage (preferred) any number of thicknesses may be welded provided the overall thickness of the stack does not exceed one inch

Fig. 12—Typical standard electrode tips and operations



2. When outside sheets are heaviest, gage in the pile-up need not be equal, but the maximum thickness ratio between any two thicknesses must not exceed 3 to 1. Up to 8 thicknesses may be satisfactorily welded in this manner but overall thickness of the stack should not exceed one inch
3. When the thinnest piece or pieces are on the outside (not necessarily equal), the maximum ratio between any two sheets must not exceed 2 to 1. Up to 7 thicknesses may be satisfactorily welded but maximum thickness should not exceed one inch.

In aluminum or magnesium alloys these restrictions are somewhat more stringent:

1. When all sheets are of equal gage (preferred) up to three thicknesses may be welded provided the overall thickness of the stack does not exceed $\frac{1}{8}$-inch for aluminum or $\frac{1}{4}$-inch for magnesium
2. When sheets are of unequal gage, up to three thicknesses may be welded provided the thickness ratio between any two sheets does not exceed 2 to 1 and the total thickness of the stack does not exceed $\frac{1}{8}$-inch for aluminum or $\frac{1}{4}$-inch for magnesium.

In order to complete the design of a spot-welded assembly properly, complete data regarding the joints must be given. To supply such information to the manufacturing division, use of standard welding symbols developed by the American Welding Society is recommended. *Fig.* 13 summarizes all this information and in use it can be simplified or modified to meet individual requirements.

MATERIALS: Ordinary low-carbon steel with from 0.05 to 0.15 per cent carbon is the most readily weldable material and the weldability of all other materials is judged therefrom. Low-carbon steel has a sufficiently high electrical resistance, a wide plastic range and offers the fewest metallurgical problems. As the carbon content is raised, embrittlement of the weld zone enters the picture and this becomes critical in the range from 0.25 to 0.35 per cent carbon. Up to 0.50 to 0.60-carbon content, satisfactory heat treatments may be applied automatically in the machine itself. Beyond this point, post-heat is of little value and the end use of the product must be considered for subsequent annealing and heat treatment.

In TABLE III are shown the relative weldability ratings of metals most commonly spot welded. The letter prefix indicates the general weldability, everything considered in relation to low-carbon steel (rated *A* or excellent). Stainless for instance, requires more pressure and more exacting control, hence its rating is *B* or good. Stainless is readily weldable, but for best results the carbon content should not exceed 0.08 per cent. The rating *C* indicates only fair weldability, while *D* indicates poor. The figure in the rating index indicates the amount of current required for a weld, hence stainless requires only 75 per cent as much as low-carbon. Materials rated *E* are extremely difficult to weld and those indicated *F* are commercially impractical or impossible.

Proprietary steels and low-alloy steels weld in a manner very much like low-carbon but, like high-carbon and heat-treatable steels, they must be post-heat treated to eliminate embrittlement.

Nonferrous Metals More Critical

In the nonferrous metals, the plastic range is smaller and they are therefore more difficult to weld. Also, surface conditions must be more accurately controlled. Some nonferrous metals, particularly aluminum, introduce further difficulties because of a tendency to pick-up or adhere to the electrodes.

Most of the wrought alloys of aluminum are weldable, but due to their low electrical resistance, more power is required. Hence aluminum requires 2½ to 3 times as much current as low-carbon steel, TABLE III. Aluminum has a short plastic range and control must be exacting. Oxide coating is undesirable and hence all aluminum alloys must be cleaned just prior to welding by pickling or wire brushing. Brass, lead, bronze, and magnesium likewise require careful cleaning.

The weldability of other metals can be judged roughly by their electrical and thermal conductivity. The higher the conductivity, the greater the difficulty in welding. Thus silver and copper are difficult to weld largely because no satisfactory electrode material is available; copper will weld readily to the electrode itself.

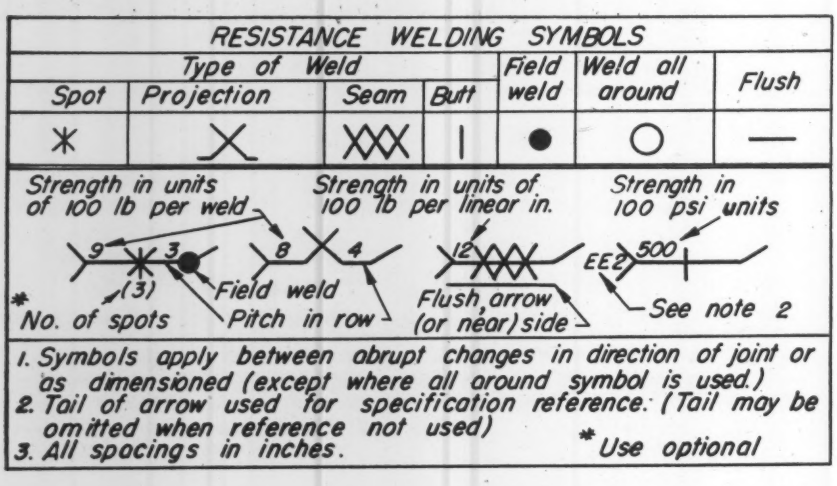


Fig. 13 — Left — Legend showing symbols for use in specifying resistance-welded joints on drawings

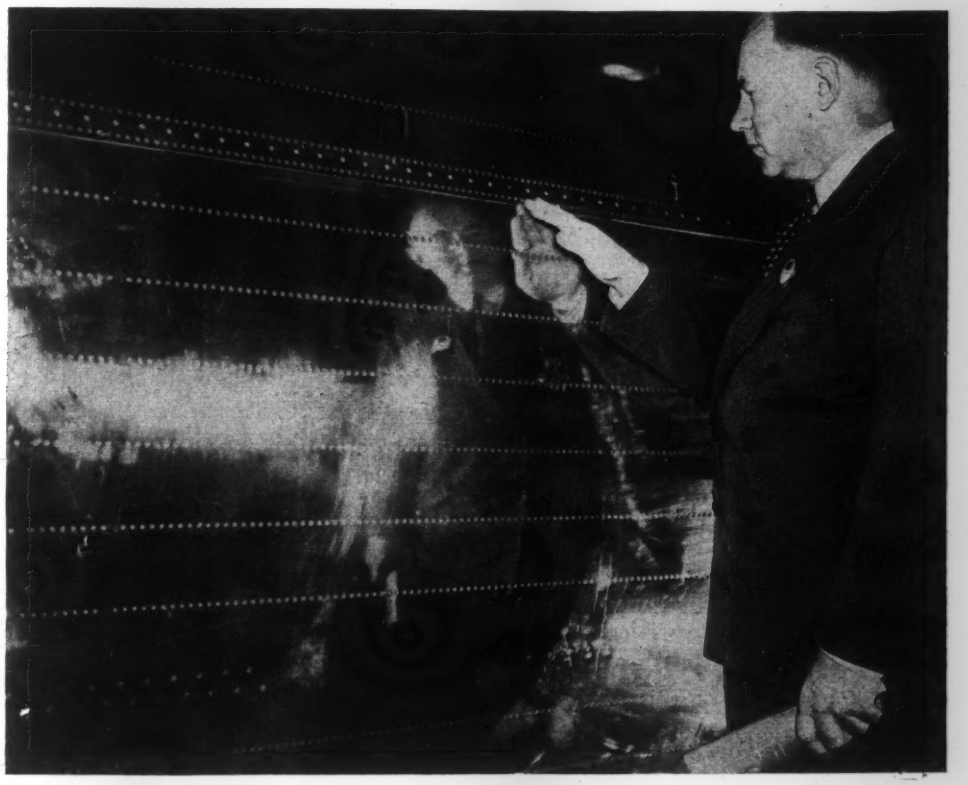


Fig. 14—Right—Spot welding is fast finding use in aircraft. Better production speed, strength, rigidity, and aerodynamic smoothness result

Dissimilar metals can be spot welded. However, many factors enter into such combinations and no specific rules can be made. The chart in TABLE IV shows most of the metals that can be spot welded with conventional methods.

Scale Greatest Hinderance

The greatest hindrance to welding is scale. To obtain best results materials should be specified as free from scale, at least in the weld zone. Some coated materials can be satisfactorily welded, others not. Terne plate can be welded, though not as readily as uncoated steel. Zinc plate welds readily but the zinc coating is destroyed in the weld zone. Tin plate can be welded without injuring the coating. Coatings such as Bonderizing, Parkerizing, Browning, or Brunofixed are impossible to weld. Sherardized sheet can be spot welded but slight rusting occurs on the weld surfaces. From a production point of view, Sherardized and electro-zinc surface coatings are recommended when rust proofing of components must be used prior to spot welding.

TOLERANCES: Generally, resistance spot welding has little or no effect on part tolerances, the actual critical dimensions of most components being dependent upon some prior method of forming. Dimensions over an assembly of two or more pieces is merely that of the sum of the various part thicknesses. Tolerances on the final assembled and welded stack, of course, are additive, being comprised of all the individual part variations. Spot welding adds no metal; actually, on cooling, the weld shrinks somewhat and along with the pressure during welding leaves a slightly hollow spot at the point of contact on each side.

Where absolutely smooth, undiscolored finish is necessary, one of the previously mentioned methods can be used for obtaining such surfaces. For economy the as-welded surfaces should be acceptable, *Fig.* 14.

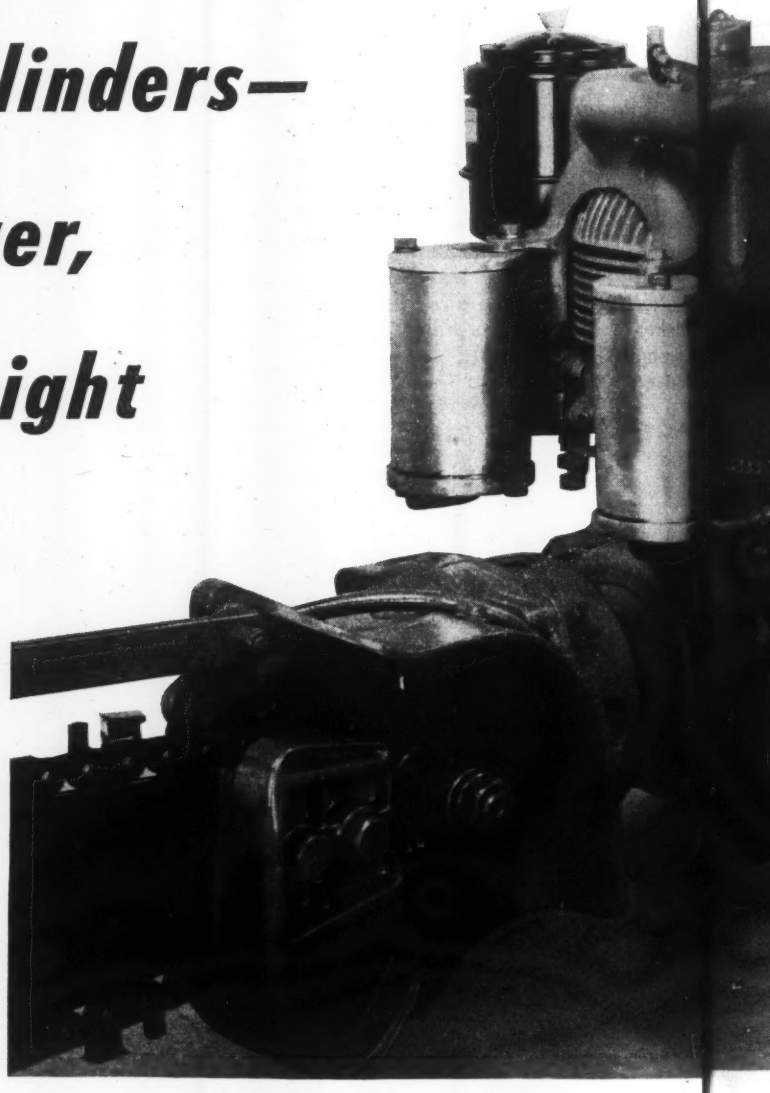
Tolerances on the fit of assembled parts to be spot welded should be as close as practicable. Poorly formed, buckled or warped parts often cause shunting of the current away from the weld. Poorly fitted parts which require the welding machine to accomplish pressing are uneconomical to spot weld in production.

Use of fixtures to locate an assembly of parts to be welded offers wide possibilities in the manufacture of highly accurate assemblies. Assembled tolerances for spot welded assemblies should be no closer than warranted by the design contemplated in order to simplify the design of the fixtures necessary. Spot spacings are normally held within plus or minus ⅛-inch of spacings designated.

Collaboration of the following organizations in the preparation of this article is acknowledged with much appreciation:

Boeing Aircraft Co. (*Fig.* 14) ..... Seattle, Wash.
General Electric Co. ..... Schenectady, N. Y.
Lockheed Aircraft Corp. (*Fig.* 9) .... Burbank, Calif.
P. R. Mallory & Co. (*Figs.* 11 & 12) .. Indianapolis, Ind.
National Electric Welding Machines Co. (*Fig.* 6) ..... Bay City, Mich.
Northrop Aircraft Inc. (*Fig.* 1) .... Hawthorne, Calif.
Precision Welder & Machine Co. (*Fig.* 2) Cincinnati, Ohio
Progressive Welder Co. (*Fig.* 4) ..... Detroit, Mich.
Resistance Welder Manufacturer's Association (*Figs.* 7, 8, 10, 13 & Table I) ..... Philadelphia, Pa.
Taylor-Winfield Corp. (*Figs.* 3, 5, and Table II) ..... Warren, Ohio
Westinghouse Electric Corp. ..... East Pittsburgh, Pa.

Aluminum Cylinders—Increase Power, Decrease Weight



Porous chromium plating in the bores of die-cast aluminum cylinders provides better heat transfer and wear resistance along with improved performance

By A. W. Mall
President
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THE design of a new engine usually comes about as a deliberate development to serve a given purpose. In adapting the various parts for economical production, there may be modifying factors such as selection of satisfactory and readily available materials or improved processing methods that may reveal unexpected potentialities.

Such was the case in redesigning the small, one-cylinder engines that are used to power a variety of portable Mall tools, *Fig.* 1. The resulting model delineates the improvements in production, weight per horse power, service life, and performance that can be incorporated in engine design through proper consideration of the materials finally selected.

As originally produced, the engines had an output of four horsepower. A single cast-iron cylinder of 2⅜-inch bore was used with an aluminum piston. Stroke was 2¾ inches and compression ratio five-to-one. Although a satisfactory design in all respects, iron castings for these engines became increasingly difficult to obtain. Experiments were begun, looking toward redesign of the engine to utilize more readily available materials. Ultimately, it was decided to use aluminum not only for the piston but for the cylinder as well.

Fig. 1—Above—Use of porous chromium-plated aluminum cylinders for this portable-tool engine reduces weight and increases service life from four to twenty times

To enable the use of these light, but soft, materials in opposition to each other, the first problem was reduction of the high wear factor. An approach was made through the use of steel liners. These were discarded when extensive tests proved that chromium could be applied directly to the walls of the aluminum cylinder, *Fig.* 2.

To handle the research and testing of this phase of the development, access was had to special labora-

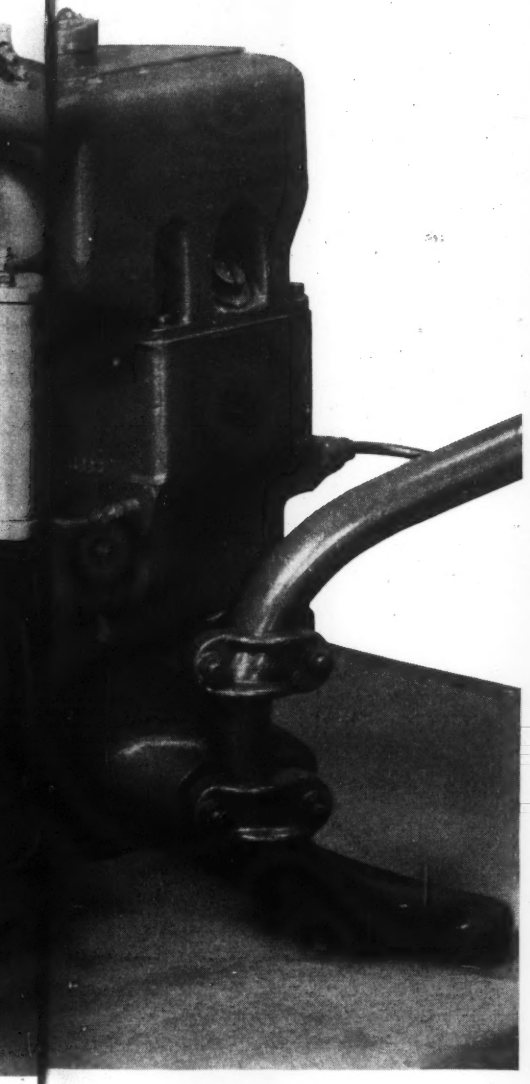


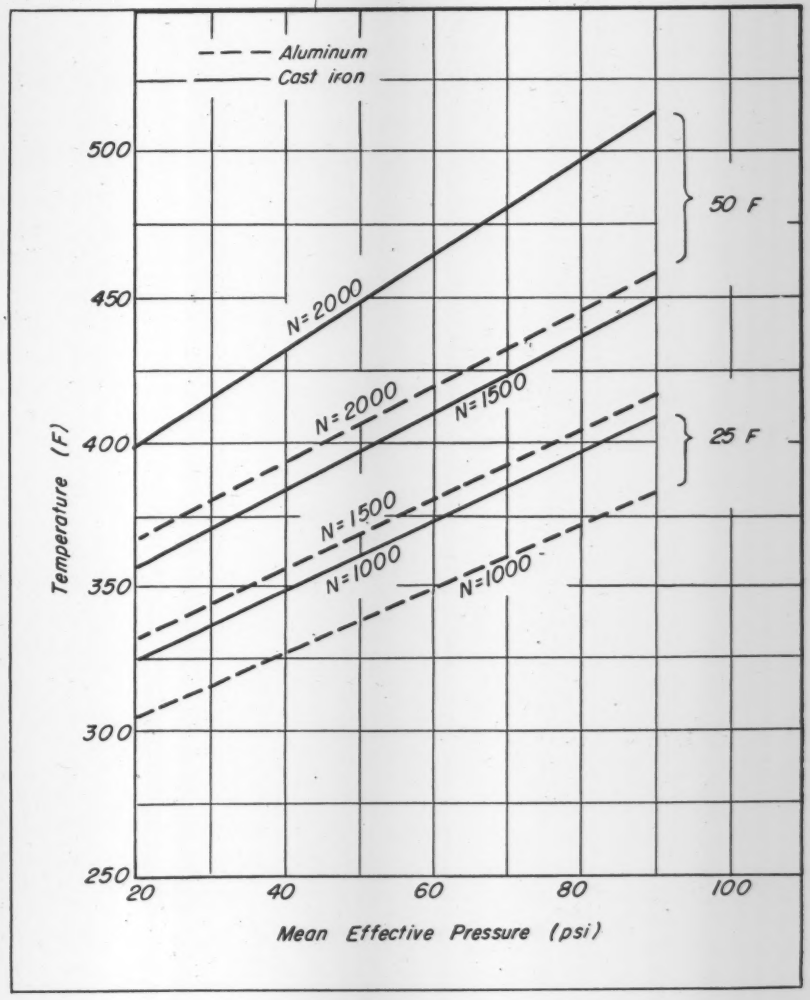
Fig. 2—Below—Section of a chrome-plated cylinder, heated to 1100 F and quenched rapidly, produced no fractures

tory facilities at Olean, New York. There, under the technical direction of Dr. Hendrik van der Horst, the chromium was applied electrolytically. The process was such that a porosity was induced on the chromed cylinder walls, to retain oil and provide a protecting film of lubricant during operation of the engine.

Tests showed that the life of the all-aluminum engine was extended as much as 20 times over that of the cast-iron model, even when the latter was equipped with nickel-steel liners. Furthermore, the design advantages, made possible by the use of this protective coating, throw a good deal of light on some interesting possibilities that await adaptation to other types of engines.

Previous data on cooling efficiency of chromium-plated aluminum cylinders, *Figs.* 3 and 4, indicated that heat transfer would be considerably better, so the compression ratio was stepped up to six-to-one. This made for an increase in horsepower, which was further raised by increased cooling efficiency cutting in half the fan power requirements. The cooling fan on the cast-iron model required one horsepower. Trouble, however, had often been encountered with preignition. The high rate of heat transfer through aluminum allowed a reduction of the fan intake diameter and only one-half horsepower is now absorbed in cooling the cylinder, which no longer rises to the temperature at which preignition

Fig. 3—Piston temperature behind top ring vs mean effective pressure of chrome-plated aluminum cylinder liners as compared with cast iron under identical operating conditions. Test was made on a Ricardo E-16-1 Comet Mark II engine



of the air-fuel mixture is likely to occur.

The problem of blow-by was made negligible, with attendant increase in both power development and easier starting, through fitting the piston with only 0.0015-inch of clearance, as against 0.007-inch in the cast-iron model. This reduction in clearance was possible because the aluminum cylinder and piston have identical coefficients of expansion. The protective coating of chromium in no way interferes with that desirable characteristic of the improved design. It is, in fact, theoretically ideal. Temperature is highest at the operating surface of a cylinder, with a steep downward gradient through its walls. By reason of this, the expansion coefficients for chromium and aluminum appear to remain closely in balance when the ratio is weighted by this condition of engine operation in reference to their respective rates of thermal conductivity, TABLE I.

In production, the ⅛-inch thick aluminum cylinders are die cast, following which the bore and both ends are finished in one operation. By diamond boring the diameter is held to plus or minus 0.0005-inch with a surface roughness of 30 microinches. A further design change involved the use of a forged aluminum connecting rod in place of the former steel forging.

Altogether, the advantages enumerated stepped up the power of the engine from four to seven horsepower. This, along with improved performance and longer service life, was achieved in conjunction with a considerable reduction in weight. From 7.5 pounds for cast iron, the weight of the cylinder was brought down to 2.75 pounds with aluminum, a saving of 63 per cent in the cylinder alone.

No change was made in the rpm, bore or stroke, a fact which is of interest in considering the greatly increased endurance provided by the chromium-protected cylinder. The utility of this endurance factor is seen more clearly in a comparison of the various uses to which the new portable power unit has been put. It is coupled with the grinders used by railroads for slotting and smoothing rail ends, and for grinding frogs, crossings and switches. On chain saws, it fells and bucks trees up to 12 feet in diameter. For cutting smaller timber, it is mounted as the power source for mobile circular saws or used with a chain bow saw. Abrasive wheels, for cutting concrete, and cement agitators are operated with it.

From this it is obvious that service life of the engine varies between different applications and conditions of use. Yet, on the heaviest equipment and work, it delivers not less than four times the service period between overhauls that could be obtained with previous models. On less rigorous use, the chromium-plated cylinders stand up as much as 20 times longer, despite the increase in power developed. These figures are supported by present operation of some 40,000 such engines, exposed to all variations of handling and care, of climate, fuel and atmospheric dust.

TABLE I

Comparative Expansion and Conductivity Coefficients

Metal	Linear Thermal Expansion at 68F (per deg F x 10^{-6})	Thermal Cond. at 20C (cal/cm²/cm/deg C/sec)	Melting Point (deg F)
Chromium (electrolytic)	4.5	0.165	3325
Cast Aluminum	12.0	0.30	1100
Cast Iron	6.6	0.12	2600
Steels	6.2–6.6	0.11	2700–2800

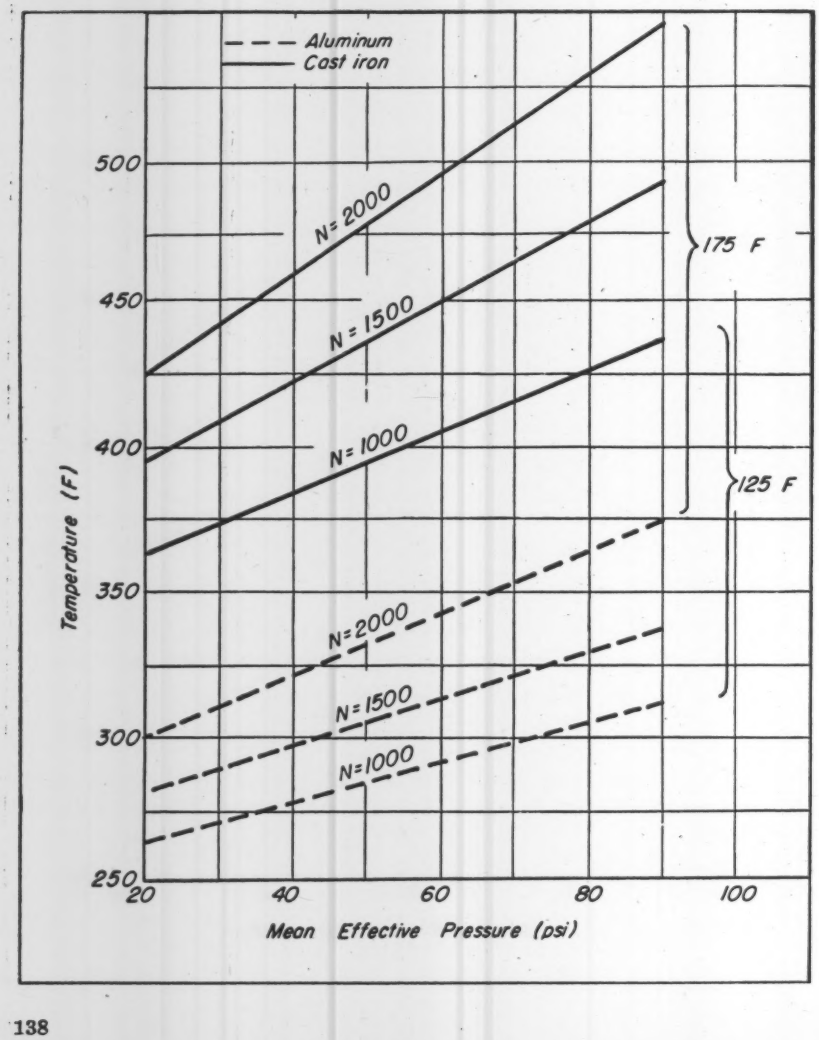


Fig. 4—Cylinder liner temperatures vs mean effective pressure of same engine as in Fig. 3. Thermocouple was installed at hot spot just below throat of combustion chamber passage

Hydraulic Seals

. . . factors to consider in selecting sliding types

By Frank Flick
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Miller Motor Co.
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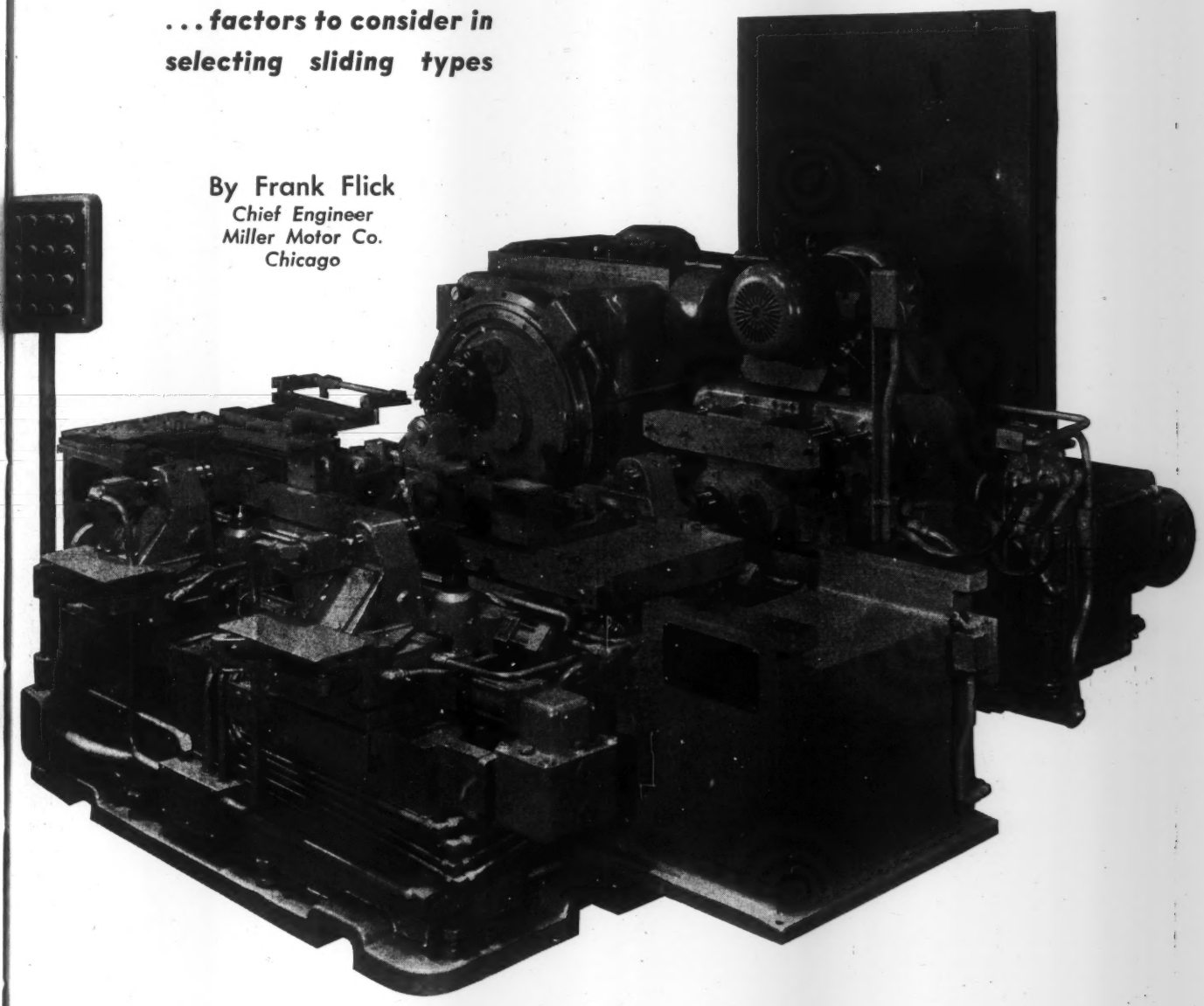


ACHIEVING leakproof operation of hydraulic units has been obstructed by the persistent belief that leakage is due entirely to the seal itself. Experience has shown that fitted cylinder parts frequently are more responsible for seal failure than are the seals. The best quality seals have allowed leakage in tests and the failure has been traced to the improper design and fitting of related parts. On other tests, inferior packings have given excellent service when used in cylinders that were soundly designed and carefully built. This situation has led to unfounded prejudice against certain types of seals. Until a broader attack is made on the sealing problem, the number of leakproof hydraulic cylinders is bound to be limited.

The seal represents the hub of the hydraulic cylinder problem. Much thought, skill and experimen-

Fig. 1—Top—For clamping and shuttling the parts from one station to another as the work progresses, fourteen high-pressure hydraulic cylinders are utilized on this Sundstrand machine for milling and reaming two holes in the flywheel housing of automobile cylinder blocks

tation have been put into its development. For many years the lack of a leakproof assembly retarded the evolution and application of hydraulic equipment and materially limited its acceptance.

New Seals Are Leakproof

Until one or two fully leakproof hydraulic seal assemblies were developed during the past few years, many modern factories had been unwilling to tolerate the messy oil leakage usually experienced in the operation of hydraulic equipment. Besides being unsightly, the oil on the floor was an operational waste and a definite safety hazard. The advantages of hydraulic operation are widely recognized, *Fig.* 1, and now that cylinders have been designed to operate successfully without leakage, a wider application of hydraulic power is becoming evident.

Along with the current renewed interest in hydraulics, a controversy regarding the use of various type seals has developed. During the past year many engineering discussions have centered upon the advantages and disadvantages of one or another type. Types of seals cannot be discussed properly without reference to application. Experience suggests that no one type of piston or piston rod seal is best for all applications, but rather that the type selected for use be determined by the benefits chiefly desired in each application.

Design engineers should become familiar with the characteristics of each type of hydraulic seal and specify the one that best suits each application. Such practice will bring more satisfaction than arbitrarily naming one type seal to serve all purposes. The application of one type of seal to all types of use may underlie part of the current controversy among engineers and some of the dissatisfaction among hydraulic equipment users. Advocates of piston-ring seals have spent many hours arguing with other engineers who prefer cup type, chevron type, O-rings, or nonexpanding metal-to-metal piston seals. Similar discussions have been led by engineers who prefer the piston rod flange seal to the chevron, O-ring, precision, and various types of metallic seals. Greater progress will be possible when the characteristics of each type of seal are recognized and regarded in relation to the complete assembly. Then the one that closely meets the conditions of each particular application may be specified.

Summary of Hydraulic Kinetic Seal Characteristics

Type Piston Seal	Nonmetallic Seals			Metallic Seals		
	Cup or U-packing	Chevron or V-packing	O-ring	Piston Ring	Metallic	Metallic precision
Type Piston Rod Seal	**Flange or U-packing**	**Chevron or V-packing**	**O-ring**	**Contracting Ring**	**Metallic**	**Metallic precision**
Adjustable	No	Yes	No	No	No	No
Service Life[1]	Very long	Long	Short	Indefinite	Indefinite	Indefinite
Leakage Past Piston Rod Seal	Zero with proper expanders	Zero with adjustment	Damp to Wet	Zero with wiper and drainback[2]	Zero with wiper and drainback	Zero with wiper and drainback
Leakage Past Piston Seal	Zero[4]	Zero	Zero[4]	Small	Much	Small
Leakage Variation in Cylinder Stroke when Temperature and Viscosity are Constant Varied	Zero Zero	Zero Zero	Zero Zero	Some Large	Some Large	Small Some
Kinetic Friction at Low Pressures[3]	Very low	Medium to high	Medium to high	Medium	Negligible	Negligible
Static Friction or Break Loose	Very low	Medium to high	Medium to high	Medium	Negligible	Negligible
Overall Efficiency[5] at Low pressures	Good	Poor to fair depending on adj.	Fair	Fair	Fair	Good
High Pressures	Very good	Poor to good depending on adj.	Good	Fair	Fair	Good
Variation of Kinetic to Static Friction at Low to Medium Pressure[3]	Very Small	Medium to high	Medium to high	Medium	Negligible	Negligible
Cylinder Bore or Piston Rod Requirements Finish	Good	Good	Excellent	Fair	Fair	Excellent
Straightness & Roundness	Fair	Fair	Good	Good	Fair	Excellent
Clearances and Tolerances Required	Very close	Fairly close	Very close	Fairly close	Fairly close	Extremely close
Maximum Operating Temperature (F)	Leather-120-150 Synthetic-120-200	Leather-120-150 Synthetic-120-200	120-200	Limited only by the maximum safe operating temperature of oil.		

[1] Long service life would be considered several million inches of pressure cycling.

[2] Metallic seals allow some leakage and when used as rod seals a drainback or return line to the oil supply generally is provided. Wiper seals operating against atmospheric or tank pressure wipe the piston rods dry.

[3] At high pressures most types of seals have small friction loss because the residual "built-in" sealing pressure of the seal becomes negligible in comparison to the load friction. Variations of kinetic to static friction at higher pressures become less pronounced. On metallic seals leakage losses are greater at higher pressures and thus efficiency is lower.

[4] Leakage is practically zero under normal pressures on double acting piston assemblies. On single acting piston assemblies the wiping action is not perfect as droplets of oil will form on the return stroke, caused by imperfect wiper action. Properly adjusted chevron packings give excellent wiping action on single acting cylinders and can be maintained without oil drippage with periodic adjustment. Cup or U-type seals can be made drip-proof on single acting units by the addition of proper cup expander rings which are nonadjustable for the life of the packing.

[5] Overall efficiency includes friction and pumping losses.

Types of Seals

Piston seals may be classified as nonmetallic and metallic. In the nonmetallic group of seals are the cup type, U-packing, O-rings and chevron or V-packings, *Figs.* 2 and 3. Metallic seals consist of the expanding or piston-ring seal, *Fig.* 4, and the nonexpanding seal such as shown in *Fig.* 5.

Piston-rod seals have a sealing action inward toward the moving rod and thus are the reverse of piston seals in performance. Rod seals consist of the nonmetallic flange seal, U-packing, O-ring, and chevron or V-packing, and the metallic types such as the contracting piston ring and the noncontracting metal seals. Characteristics of piston and rod seals are classified in the accompanying tabulation.

Efficiency Is Primary

Many considerations should guide the engineer in his choice of piston and rod seals. Efficiency is a primary consideration and is affected by pumping losses and friction losses. Consistency of thrust output is affected directly by mechanical efficiency and indirectly by pressure drop caused by pumping losses. A third important fac-

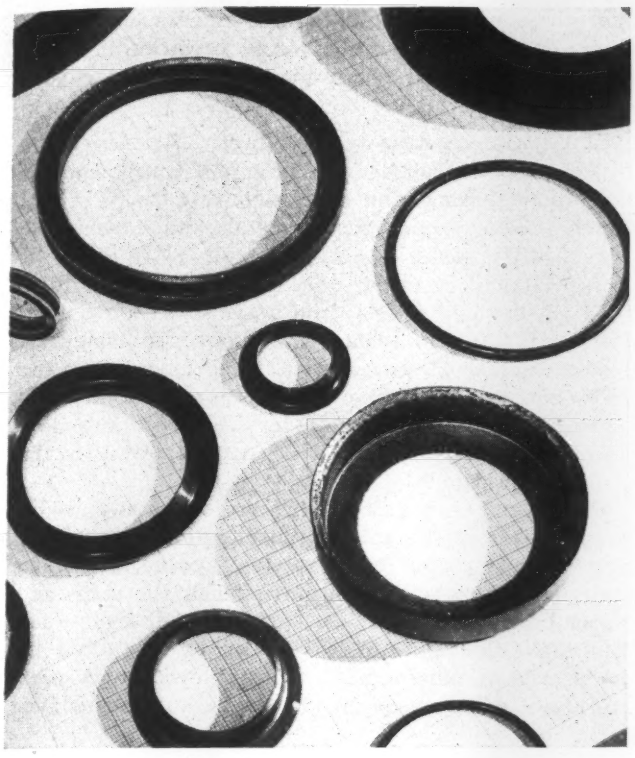


Fig. 2—Left—Various types of synthetic-rubber seals, illustrating a flange seal, cup seal, O-ring seal, U-packing, and chevron or V-packing sealing units

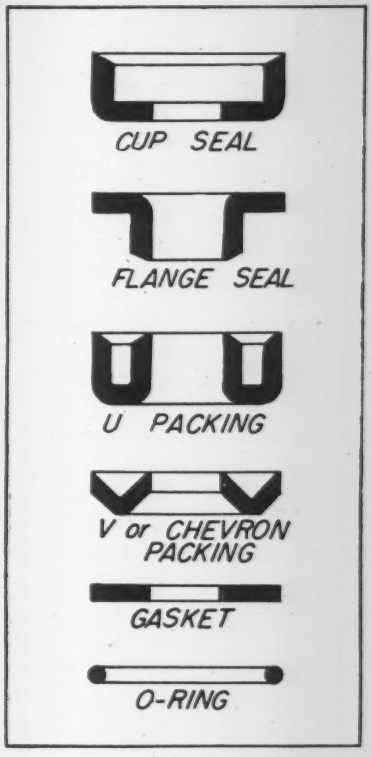


Fig. 3—Right — Sectional views of various types of non-metallic seals

tor to bear in mind is variation of controlled speed for feeds which is affected by leakage and viscosity, both of which in turn are affected by temperature. Operating temperature is influenced by pumping losses and friction. Smoothness of operation is a fourth consideration and is affected basically by the variation in kinetic and static coefficient of friction; large variation usually results in jumpy action and chatter.

Certain external elements also have a bearing on the selection of hydraulic seals. The possibility exists that a wide variety of hydraulic fluids may be used other than those recommended, due to locale, to personnel selecting the operating fluid or servicing the machine, or to blunders. The alignment problem may be crucial on some types of machinery and may be influenced greatly by the degree of skill of the workmen who install and service the cylinders. The type of service personnel in the user's plant must be considered, including those in some foreign countries where good mechanics may be scarce. Heat conditions might be detrimental. Internal heat generated by the cylinder itself and heat generated in the circuit due to pumping through pressure relief valves must be dissipated. External heat from sources such as furnaces must be predetermined and counteracted or, if not counteracted, must be taken into account in the selection of seals.

General-Purpose Piston Rings

A good cup or U-type seal (both are called cup seals in this discussion) of high grade leather properly impregnated makes an excellent general-purpose seal. If the component parts of the piston assembly and the tubing in which they work are designed and machined to proper specifications and precision, almost friction-free operation is obtained. High efficiency is always indicative of long life. And since efficiency higher than 98 per cent is obtained with properly designed self sealing cup type packings, almost indefinite life is assured to the seals and assembly providing that no overheating or mechanical damage occurs. It should be remembered that low efficiency means short cylinder life, high operating cost, more likely replacement expense, as well as less productive work.

Cause of Chatter

Minimum variation of kinetic and static coefficient of friction is obtained with this cup type seal. This seal provides smooth, chatter-free operation even with light loads and feeds. Numerous tests which have been made in the cylinder field as well as friction tests in other fields such as brake linings, have established the fact that chatter or jumpiness is primarily caused by alternate seizure and release of contacting frictional surfaces. The seizure occurs when a static condition exists. It is necessary to build up sufficient pressure to break away from this static condition.

If there is an appreciable reduction in the friction resistance from the static to the kinetic condition, as soon as breakaway takes place a sudden forward jump will occur with resultant drop in pressure of the operating medium. As pressure drops, the cylinder motion stops and a static condition again exists. Pressure once more builds up until the piston breaks away again. Rapid repetition of this action is called chatter. The percentage of friction drag to total load is greater with light loads than with heavy loads. That is why more chatter ordinarily occurs with light loads. Since the cup type is self-regulat-

ing, the percentage of friction with light loads is proportional to the internal pressure. Proper design of cup seals and adjoining parts allows cylinder operation with light load at minimum friction, and breakaway at two to five pounds pressure can be maintained regularly when no load is attached.

Advantages of Cup Seats

Cup or U-type seal assembly, *Fig.* 6, holds pressure indefinitely without pumping loss and permits zero passage of oil past the piston assembly and seal. Cooler operation results because there is no heat generated from by-passing oil. Operation without leakage also eliminates wire drawing of the oil with possible localized hot spots under pressure which cause breakdown of the oil, varnishing, and subsequent failure of precision valve and pump parts. The cup or U-type seal has advantages in many applications:

FEEDS: Cup construction eliminates the variation in flow past the piston due to viscosity change of the oil. This permits feed rates to be maintained at exact settings with practically zero percentage of feed variation, regardless of temperature variation. An example of this is on the final grind of internal ball bearing races. Consistent feed and chatter-free operation were outstanding, even on the lightest cuts and finest feeds.

CLAMPS: In some clamping operations distortion must be held to a minimum and balanced loads of multiple cylinder clamping must be held to the least variation. A typical example is the external clamping of a flywheel housing during boring or milling operations where a number of cylinders are used to clamp the housing radially. Any variation in clamping pressure would result in distortion of the housing, *Fig.* 1.

ECONOMY: Because of the high efficiency of the cup or U-type seal, smaller pumping equipment, cylinder bore, piping, and other apparatus may be used which reduces space requirements and considerably lowers initial costs.

Care should be exercised when selecting a cylinder with leather cup type piston seals since cup pull-out and short life can result from improper design and specifications. However, experience has proved that a leather cup seal assembly, properly designed and built, will give fully as long service as other parts of machines on which they are installed, even on fast cycling operations.

O-ring and chevron seals are not commonly used as piston seals on general-purpose cylinders. The O-ring is a circular cross-section synthetic packing housed in a rectangular groove much the same as a piston ring. Although excellent for static seals where they have indefinite life, O-rings have limited life when used as moving seals. The chevron or V-packing is not widely used on pistons because adjustment is difficult.

Metallic Piston Seals

The characteristics of metallic seals recommend them for many specific applications. The piston ring seal, *Fig.* 7, generally utilizes automotive step type piston rings and is low in initial cost. In opera-

Fig. 4—Left—Metallic expanding or step type automotive piston ring seal

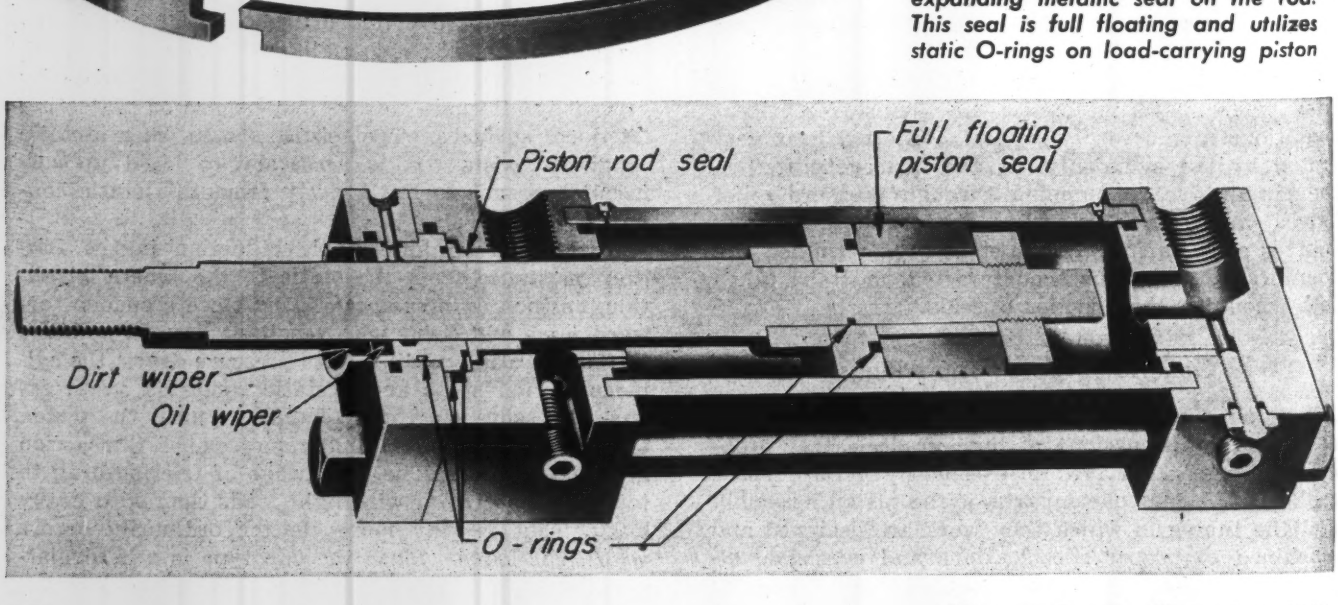


Fig. 5—Below—Cutaway view of a precision-seal cylinder utilizing a non-expanding metallic seal on the rod. This seal is full floating and utilizes static O-rings on load-carrying piston

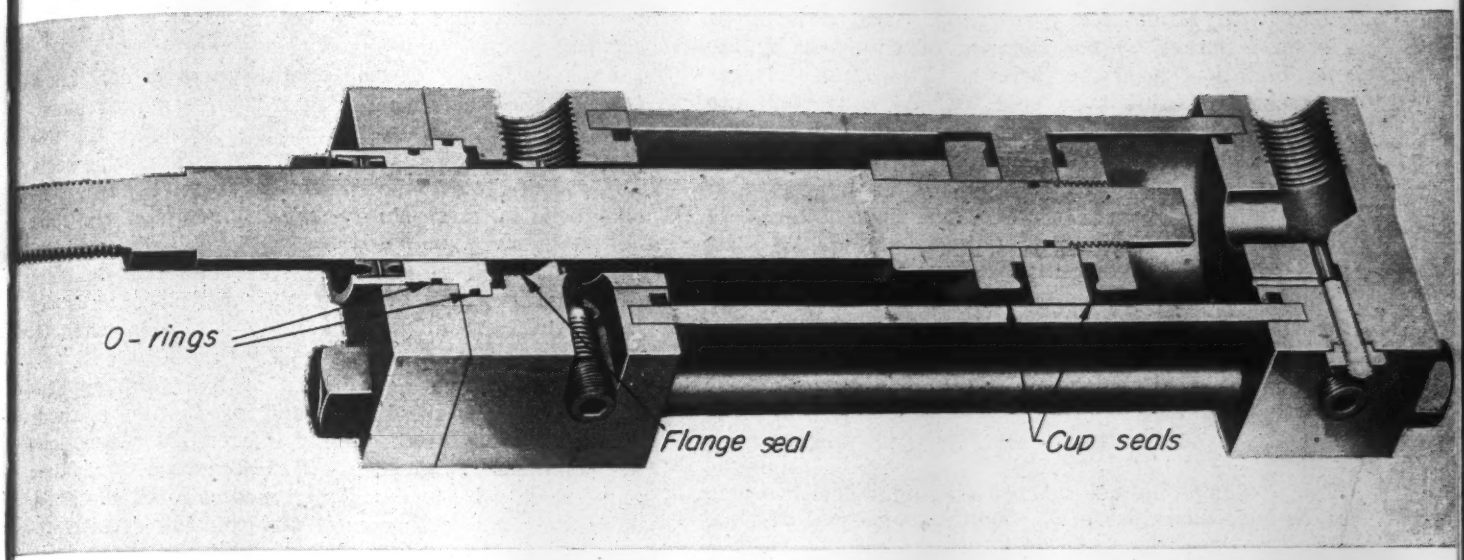


Fig. 6—Cylinder using cup seals, shown in cutaway. These seals hold pressure and provide cooler operation

tion it evidences a medium amount of oil leakage and friction loss. Uneven feed rates caused by varying viscosities of operating oil and varying piston clearances in the cylinder length are the main objections. Ring seals generally are subject to chatter on light and fine feeds. Piston ring seals are useful on cylinders that are to be operated in areas where no maintenance facilities or trained service personnel are available, as in some foreign export service. Also they are excellent where high temperatures are encountered.

Metallic nonexpanding seals may be classed as metallic type and metallic precision type. In the metallic type normal piston clearances are maintained and consequently the seal has low initial cost. It is practically friction free but permits considerable leakage. On fast cycling feed tables such as surface grinders, this metallic type is very serviceable. The considerable leakage of this type seal is considered satisfactory because with the fast cycling of the feed table the percentage of leakage to the total volume of oil being pumped into the cylinder is small. Recently, however, the variation in feed rate on these tables due to viscosity change of the oil under varying temperature conditions has been under discussion. If this percentage variation is considered too great when nonexpanding metallic seals are used, the leather cup, the precision metallic seal, or the piston ring type might be substituted. Additional data will be required to determine which of these three seals is best for this application.

Precision Metallic Seals

The precision type nonexpanding metallic seal, *Fig.* 5, is high in initial cost since extremely close tolerances are maintained between piston and cylinder barrel. High efficiency and smooth operation are obtained with very small oil leakage. The precision seal is adaptable for applications where minimum friction is a primary requirement and where a small amount of leakage past the piston is not objectionable. Cylinders with precision seals are used for power feeds on grinders and other machines for performing fine-finish operations.

On high-temperature applications where heat in excess of 130 F. is encountered and cannot be eliminated by circuit design, by using heat exchangers or by water cooling the cylinder, metallic seals on the piston assembly are recommended.

Piston Rod Seals

A flange or U-packing on a piston rod acts similarly to a cup packing inside the cylinder barrel and the advantages that apply to one apply to both. Flange packing assemblies that are properly designed and built will give leakproof nonadjustable operation over long periods of time and thus provide a good general-purpose seal.

Care must be taken always in the selection of this type of seal because if no provision is made for wiping the piston rod it will come out of the cylinder with oil on its surface. In such case an accumulation of this oil will collect at the bushing on successive return strokes of the piston rods, and eventually will cause dripping. Designs are available, however, for providing perfect wiping action with nonadjustable self-regulating flange seals.

In addition to the advantages of low friction, self regulation, and chatter-free operation, one of the best features of this flange type seal is that it does not require manual adjustment during its entire life nor is there any need for periodic removal of shims. A packing with adjustment or with removable shims is only as good as the mechanic who assembles and services the unit .

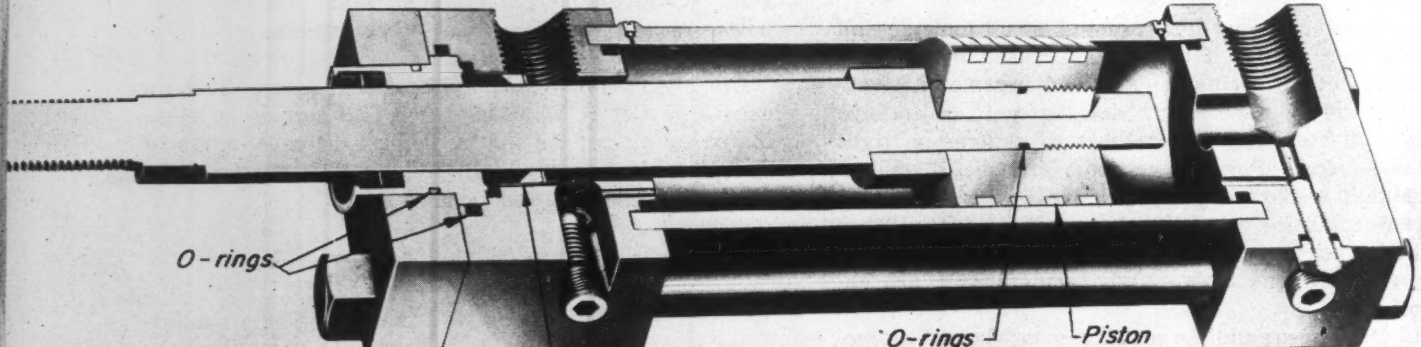
O-ring seals on the piston rod generally show small seepage, require high break-loose pressure, and have high running friction when operating at low pressures. Service life is limited.

Cylinders with chevron or V-packing for the rod seal usually are manufactured and marketed as cylin-

ders with adjustable type seals. The adjustment is made either by the removal of shims or by the tightening of adjusting screws. The danger is ever present that this type seal will be converted into a compression packing with resultant high friction when assembled by the unskilled factory or maintenance worker.

Metallic piston rod seals of the contracting type as well as the metallic and precision metallic seals are subject to leakage to such an extent that oil wiper seals are required along with an external drain-back to the tank. This consists of a drain line connected to the chamber between the pressure seal and wiper seal which returns to the reservoir the oil that leaks past the pressure seal. The oil wiper has to operate only under exhaust or return line pressure.

Fig. 7—Piston-ring-seal cylinder utilizing automotive step type rings shown in Fig. 3. Seal has low initial cost and is useful where a medium amount of oil leakage and friction loss is permissible



The tabulation on Page 140 gives operating characteristics of properly designed seal assemblies built to correct specifications. In other words, it shows seals at their best. It is unwise to condemn any type seal until it is proved conclusively that the seal is at fault rather than the poor design or the fitting and finishing of the component parts. It is likewise unwise to condemn any type of seal because of misapplication on a particular job.

Static Seals

Static seals at the juncture of the tubing with the cylinder head and the cap, and in some designs at the juncture of the piston rod bushing and the cylinder head, are highly important to satisfactory cylinder operation.

Gaskets have been the conventional type of static seals and have done a fair job. Under shock loads and repeated stress, however, distortion of metallic parts results and leakage occurs after a period of service.

Proper design of the metal parts which takes into account deflection rather than strength alone, overcomes this weakness. Today, however, the use of static O-ring seals or other self-sealing type seals are recommended instead of gaskets. The O-ring should be located on the inside diameter of the tube so that under repeated stress or shock loads considerable distortion of the head, cap, tie rods or bolts can occur without leakage. No special care is required in tightening the bolts or tie rods when O-ring static seals are used.

The tremendous advantages of hydraulic application to modern machinery and production methods will be realized more quickly if artificial restrictions are avoided. Engineers will accomplish their aims more readily by utilizing all types of available seals, basing their selection each time on the specific requirements of the job in hand. And when leakproof operation is recognized as the satisfying result of the correct design of all components of the sealing assembly rather than of the seal alone, real progress will be made.

Glass that Folds

Folding glass, to eliminate the narrow rear vision strip formerly necessary in convertible automobile top construction, has been developed by the Pittsburgh Plate Glass Co., according to Dr. J. H. Sherts, director of product development.

Used for the first time in the new Hudson Convertible Brougham, the development permits full-vision rear view as in stock model cars. Formed of a special plate glass-plastic sandwich, the glass folds like an accordion on a plastic joint connection, when the top is lowered.

PLATINGS for MACHINE PARTS

... their selection and application for decorative and functional purposes

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IN DESIGNING plated machine parts for optimum service it is necessary to keep in mind the relationship of the basis material, the plating metal and the service conditions. Proper choice must be made in combination of basis metal and plated metal, in the preparation of the basis metal for plating, and in the method of electrodepositing the metal plate. All of these factors are interdependent in determining the performance quality of the plated part.

Tensile strengths, ductilities, and hardnesses of electrodeposited metals available for engineering applications in machines are shown in Table I. Properties in the ranges indicated can be obtained by varying plating conditions. With such knowledge, proper selection can be made regarding requirements in surface strength of plated components. Of course, all metals shown in this table do not have the same corrosion characteristics. Because of this, the conditions of service must be considered.

Properties other than corrosion resistance often dictate the selection of a plated metal. For instance in wear service some plated metals give outstanding performance because they have low friction and favorable "oilability" characteristics, *Fig.* 1. In particular, hard chromium is valuable for improving the wear resistance of surfaces rubbing together under locally high pressures. Examples include rotating shafts, cam surfaces and valve seats. For each application, there is a proper thickness of hard chromium plate. Some of these values are shown in TABLE II. Not all chromium plate is exceptionally hard, as shown by the data in TABLE I. Plate having hardness of 325 to 575 Vickers can be machined.

Various frictional coefficients for different plated bearing surfaces have been reported, but the data are of doubtful value for comparison purposes because the conditions of testing were seldom the same. However, service data have conclusively shown that electroplates such as silver, silver-lead, silver-lead-indium, lead-tin, and lead-tin-copper alloys have outstanding bearing characteristics.[1, 2, 3]

Commercial methods are available for electrodepositing copper, brass, nickel, iron, chromium, nickel-cobalt alloy, gold, silver, and if desired, lead, zinc, cadmium, tin, copper-tin alloys. Special alloys produced by electrodeposition are numerous and have good industrial possibilities. They include: Silver-lead, lead-

[1] References are tabulated at end of article.

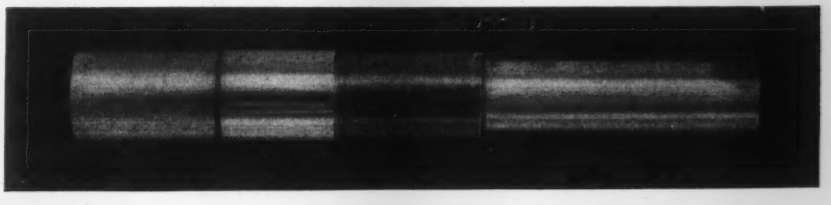


Fig. 1—Plating of shafts provides desirable low-friction characteristics

tin, tin-zinc, alloys of tungsten with iron, nickel and cobalt. Tungsten-cobalt alloy electroplates have been shown to be heat treatable to produce precipitation hardness that is retained at very high temperatures.[4] For this type of service chromium plate has been successfully retained at temperatures estimated to be 3000 F.

Designs more and more involve appearance as well as efficiency for doing the job, *Fig.* 2. Copper-nickel-chromium and nickel-chromium plate combinations are still outstanding for retention of the attractive, tarnish and corrosion-resistant finish of the new machine. Improvements have been made in the decorative finishing, but to a lesser degree than in functional plating and electroforming. Zinc plate is extensively used for corrosion protection in industrial atmospheres where appearance is not particularly important. In salty atmospheres, cadmium plate is preferred to zinc for protection of steel. A new alloy, tin-zinc plate with protective value for steel excelling that of pure zinc and cadmium, has been described by British investigators.[5]

Chemical Treatment Increases Corrosion Resistance

World War II revealed an important situation in protection of machine and equipment intended for or likely to be used in the tropics. Zinc and cadmium, so adequate for protecting steel in temperate climates, are not entirely adequate in the tropics. For use in both types of climates benefits are realized by chemical treatment of zinc and cadmium plated parts in chromate solutions. Research is under way on improved protection in tropical exposures.

In selecting protective platings there are two important factors to consider: Galvanic action and corrosion products. These are dependent upon environment and the subject is too large for discussion in this article.

There are important metallurgical factors involved in the proper preparation of the basis metal for receiving the plate when service will introduce high stresses in the region of the surface. These are: Stresses resulting from surface treatment, fragmentary metal on the surface, disturbed crystal structure differing from that of the body of the metal, and mechanically weaker metal in the outermost surface layer that will have to support the plate. All of these effects are introduced to some degree by machining, rolling, grinding, and other surfacing operations normally used in the machine tool industry. It must, therefore, be fully recognized that there is a surface metallurgy situation to be understood and properly accounted for in engineering plating. Heretofore, surface metallurgy in plating or electrodeposition of metals, was tacitly assumed to be adequately taken care of if corrosion and/or appearance were good enough. This assumption is not satisfactory where optimum functional performance is to be attained in engineering service.

Since stress is so much associated with performance of metals, TABLE III,

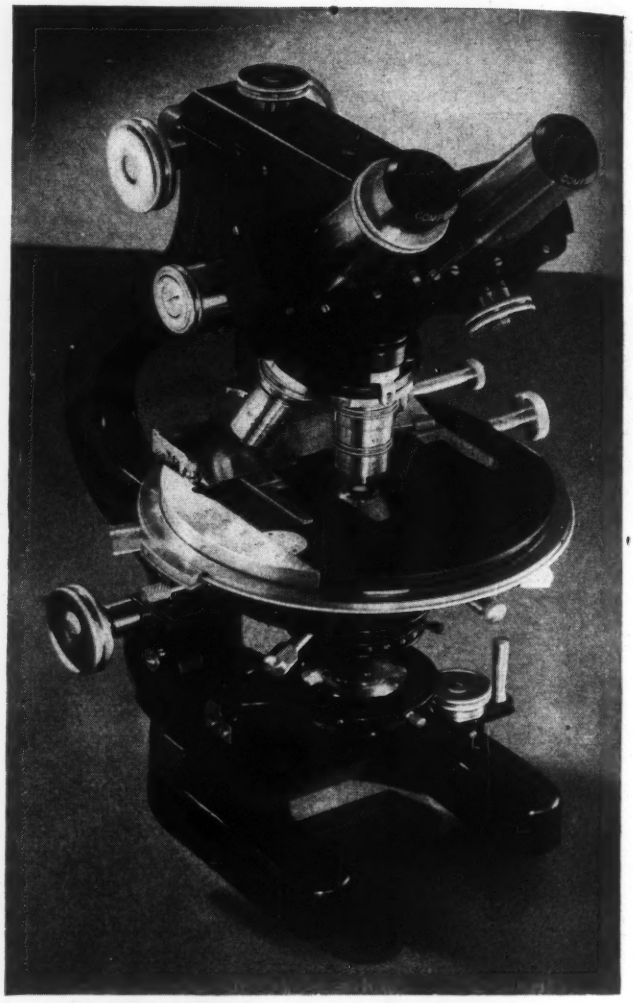


Fig. 2—Above—Plated parts improve appearance, resist wear and corrosion and permit ease of movement

TABLE I
Physical Properties of Electrodeposited Metals*

Deposited Metal	Plating Bath	Hardness (Vickers)	Tensile Strength (psi)	Elongation in 2 inches (per cent)
Copper	Acid sulphate, no addition	81	36,150	22
	Acid sulphate with molasses	81	33,000	21
	Acid sulphate with molasses & thiourea	170	80,280	3
	Fluoborate	<40 to 67	17,000 to 34,500	3.5 to 8
Nickel	Sulphate-chloride-boric	113 to 329	54,500 to 87,800	4 to 22.5
	Sulphate-boric	205	89,000	12.5
	Chloride-boric	141 to 187	58,900 to 63,000	19.5 to 22.5
	Bright, with organic	470	216,400	2.0
Nickel, annealed	Sulphate-chloride-boric	55 to 65	48,000 to 52,000	50 to 55
Nickel-cobalt	Sulphate-chloride	416	209,600	3.5
Chromium	Chromic-sulphuric acids (low temp.)	745 to 940	15,000 to 17,000	—
	Chromic-sulphuric acids (high temp.)	325 to 575	70,000 to 80,000	—
Iron	Chloride	—	47,500 to 110,000	10 to 50
Silver	Cyanide	90–92†	47,600 to 48,600	12 to 14
Silver, annealed	Cyanide	45	25,000 to 27,000	69 to 84

* Range of values indicates spread of reports of various authorities.
† Rockwell 15W.

the machine designer making use of plates must be aware of this situation and select his metals accordingly. Most particularly, he should secure advice from those to whom plating is a metallurgical and electrochemical engineering operation.

Application of hard chromium plate to sharp corners which will be highly stressed requires careful consideration in design. Preferable are rounded corners and broken edges since they are less severe stress raisers. However, in many machine parts breaking the edges, rounding the corners, and removing the burrs are prohibitively expensive. This condition has been at least partially alleviated by the recent development of the electrolytic deburring process. Burrs from stamping, grinding, machining, cutting-off, etc., are removed without mechanical action. They are removed about as easily from relatively inaccessible locations as from outside, readily reached projections. All sizes of burrs are not removed with equal facility. There must be some degree of uniformity of the burrs and accessibility to them.

Simultaneously with electrolytic deburring, the surface of the metal can be electrolytically polished for improvement in appearance, easier cleanability, some improvement in resistance to rusting or tarnishing and ease in assembly of intricately matched parts. In addition, electropolishing serves as an excellent preparation for heavy electroplate. Maximum bond and adhesion strength[6] of the electrodeposited metals also is provided by electropolishing, *Fig.* 3, prior to plating. The electropolished surface is freed from damaged and stressed metal, without introduction of any mechanical work. In other words, the surface is "mechanically" clean, a very important condition for maximum performance of engineering electroplates.

Machining Can Introduce Stresses

Metal surfaces can be seriously damaged by machining, grinding, or polishing operations, even though surface appearance and smoothness are satisfactory. For example, the injury inflicted on spring steel by grinding was found in one case to result in a tensile stress of 270,000 psi at 0.0001-inch below the surface. This value was just slightly less than the fracture point of the steel. Any additional stress-raising operations, such as pickling prior to plating might well have produced a greater stress, resulting in surface cracking and failure. Electropolishing, however, can remove the stress-surface layer, which is usually not more than 0.0005-inch thick, without introducing local stress.

Combining of basis metals and electrodeposited metals requires proper relationship between hardness, ductility, strength, and chemical resistance in the intended application. The benefits gained by applying a hard chromium plate will largely be lost if the basis metal is not sufficiently hard to support it properly. For best service in resistance to abrasion and wear, *Fig.* 4, the basis metal should be at least as hard as 50 to 55 Rockwell C. For some applications 60 Rockwell C will be required. Great hardness of basis metal is not required, however, if a relatively soft, ductile metal like copper or silver is to be applied. Thus, an understanding of the service stress of a plated machine part is valuable in selecting the correct combination of metals for a given application.

TABLE II

Recommended Thicknesses for Metal Platings

Part	Service	Plating	Thickness (inch)
Bearing	Journal	Silver or silver-lead	0.001 to >0.060
Bearing	Journal	Lead, lead-tin-indium or copper-lead-tin	0.001 to 0.007
Die	Metal drawing	Chromium	0.0005
Mandrel	Electroforming	Chromium	0.001
Mold	Forming resins	Chromium	0.00003 to 0.005
Pinion	Carburizing stop-off	Copper	0.0003 to 0.0005
Pinion	Nitriding stop-off	Copper-tin	0.00035
Punch	Metal blanking & drawing	Chromium	0.0003 to 0.001
Rolls, engraving	Printing & engraving	Chromium	0.0005 to 0.002
Rolls, pressure	Milling rubber & plastics	Chromium	0.001 to 0.005
Rolls, steam pressure	Drying	Chromium	0.0003 to 0.001
Shaft (built up)	——	Chromium	0.001 to >0.030
Shaft (built up)	——	Nickel	0.001 to >0.030
Shaft (built up)	——	Iron	0.001 to >0.030
Tubing	Acid solutions	Nickel	0.003 to 0.010

This relationship of strength factors is clearly shown by tensile tests of heavily plated parts.[8] When SAE 1020 steel, cold drawn, to 100,000 psi tensile strength, is properly prepared for plating, tough nickel can be electrodeposited on it so that, in tension perpendicular to the plate interface, fracture occurs at 90,000 psi as a typical ductile fracture entirely in the nickel plate. When the steel is not properly cleaned (referring simply to removal of oils, greases, etc.), fracture will occur at less than 20,000 psi as a sharp separation between the steel and the nickel plate. Between these two limits, fractures can occur at intermediate values depending upon the mechan-

Fig. 3—Spur and pinion gears before electropolishing, left, and after electropolishing, right

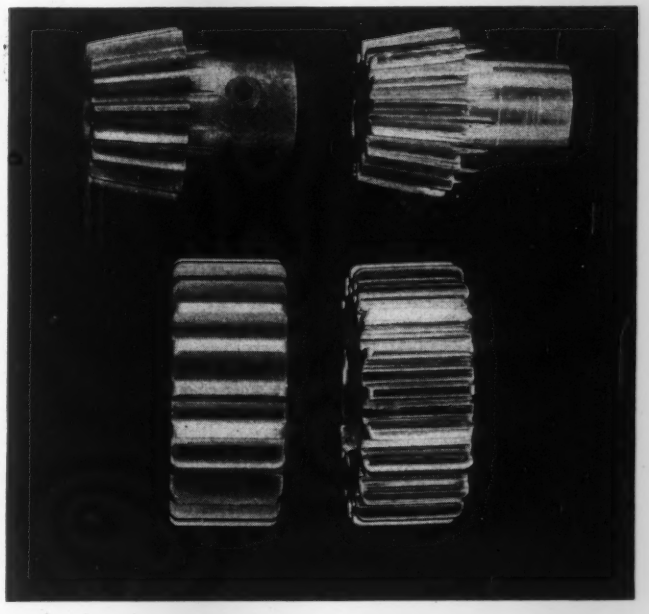


TABLE III
Stresses in Electrodeposited Metals*

Deposited Metal	Plating Bath	Stress in Tension (psi)
Copper	Copper cyanide	6,400 to 9,900
	Rochelle copper cyanide	8,700 to 14,700
	Proprietary bright bath	–3,800 to –5,000
	Copper sulphate	0 to 1,400
Nickel	Sulphate-boric acid	16,400 to 20,700
	Sulphate-chloride-boric acid	0 to 29,600
	Chloride-boric acid	27,000 to 41,000
	Saccharin fluoborate	15,800 to 25,200
	Proprietary bright bath	–7,500
Chromium	Chromic acid (low temp.)	14,000 to 37,000
	Chromic acid (185 F)	58,000 to 63,000

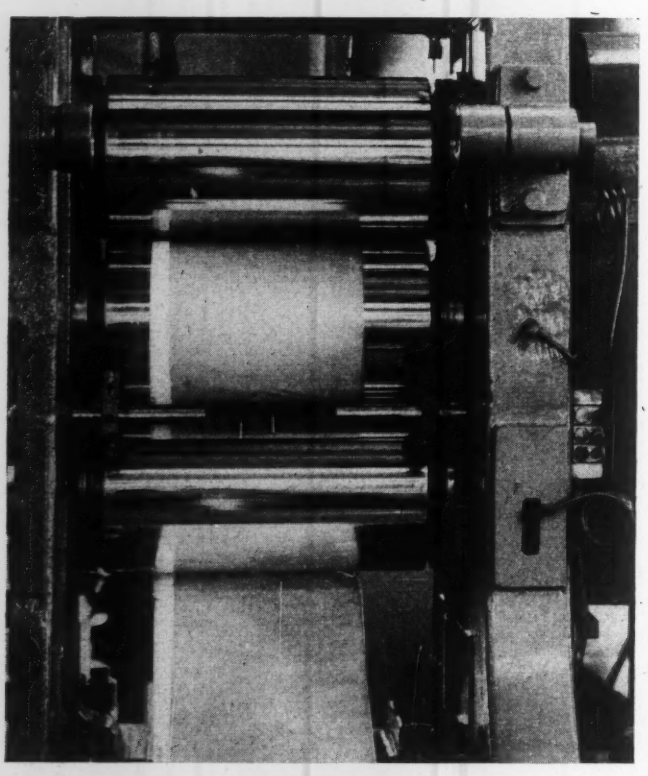
* Range of values indicates spread of reports of various authorities.

ical cleanliness of the steel, meaning freedom from surface metal weakened by machining or other mechanical operations. After a light cut-off operation on a lathe, tensile failure of a subsequently applied nickel plate was found to occur at 35,000 psi in a typical brittle fracture. Examination of the bond zone of the plated half of the specimen showed complete coverage with "brittle-fractured" steel. Electroplate adherence on this part was all that could have been expected, yet the plated part would have failed in any service which might have introduced stresses exceeding 35,000 psi in the zone of the plate-to-steel interface.

While steel finished so as to show a 45,000 to 50,000 psi fracture with nickel would be unsatisfactory, it would be suitable for a thick silver plate, for which as-plated tensile strength is at a maximum about 48,000 psi. Clearly, then, the factor of surface strength of the basis metal is highly important in the application of hard chromium plate and in building up such parts as shafts, gears, cams, etc.

Diffusion effects between plated and basis metals should also be given consideration. These effects are sometimes useful. For example, service at high temperatures may result in beneficial alloying that will improve the mechanical properties of the interface zone, as is the case for the silver-plated steel. However, diffusion at high, or even low, temperatures might produce injurious effects, like the formation of brittle zinc-iron alloys with poor strength. Even diffusion at ordinary temperatures must be taken into consideration. For example, an insufficient thickness of copper on zinc die castings will be completely alloyed in normal service, and result in blistered nickel plate.

Fig. 4—Chromium-plated coating rolls resist abrasion and wear from rubber and plastics



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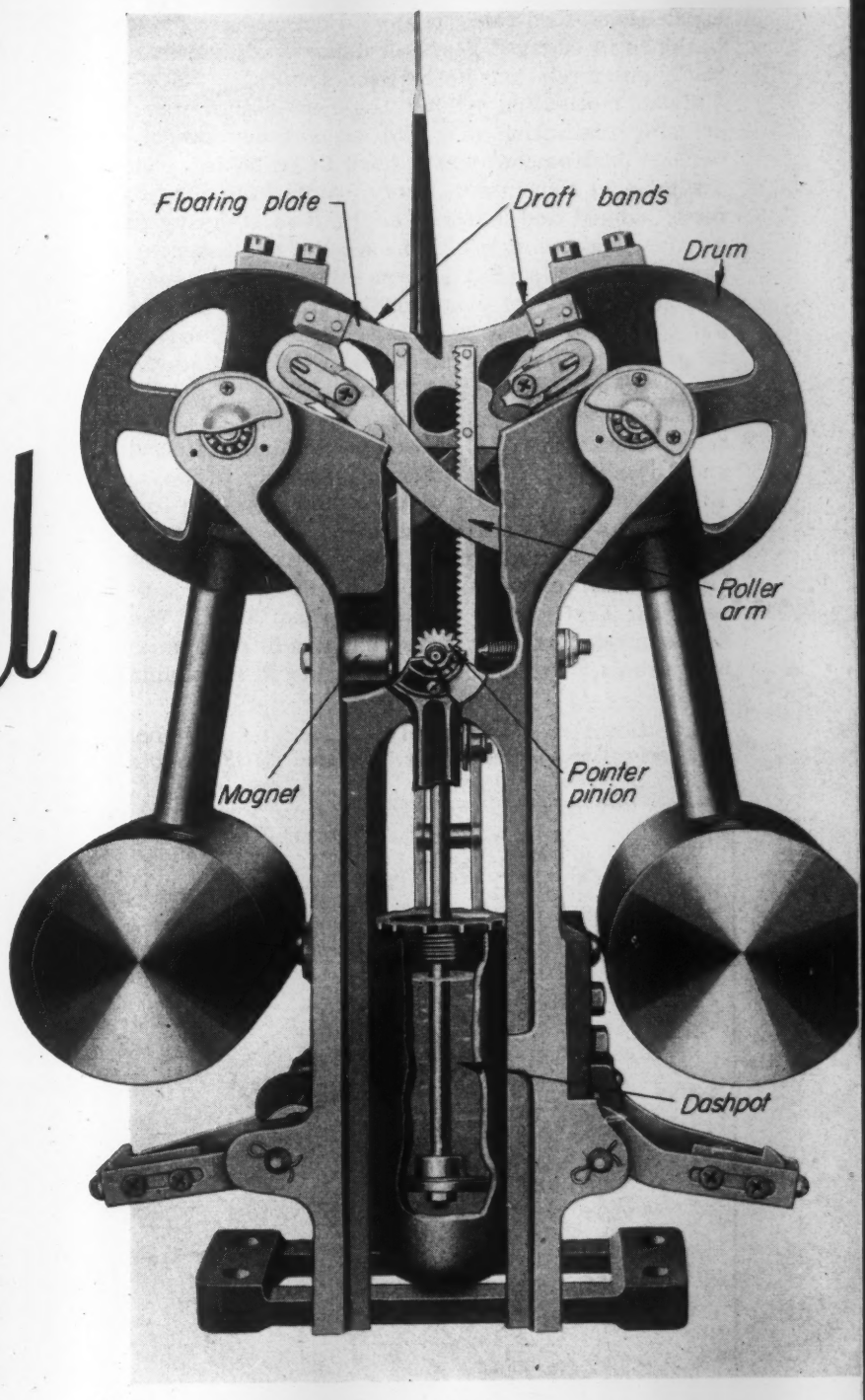
"Personality" Gets the Job

PERSONALITY is the primary basis on which young engineers are hired, according to a recent report of the Engineers Joint Council. This conclusion was based upon the answers given by 104 employers to questionnaires sent out by the "Committee for Survey of Employer Practice Regarding Engineering Graduates." Nine considerations upon which selection was based were given and the employers asked to place these in the order of importance. Ratings given were:

1. Personality
2. and 3. Scholastic record; indicated promise of development in specific field of engineering
4. Engineering experience
5. Evidence of ability to co-operate with others
6. Recommendations by qualified persons
7. Indicated promise for executive development
8. Standing of college from which candidate was graduated
9. Salary requested.

The report summarized desirable traits as "A well rounded individuality with a good personality, qualified by education and experience to make a good engineer."

New Dial Scale



. . . achieves direct linear relationship between pointer movement and magnitude of load . . . incorporates novel pendulum lock

By O. S. Carliss

Chief Engineer, Scale Division
The Yale & Towne Mfg. Co., Philadelphia

REPRESENTING the first genuinely basic new development in dial scale design to appear in many years, the Magnetrol, developed by Yale & Towne, combines maximum sturdiness and simplicity. It provides a simple mechanism in which angular movement at the pointer is in direct linear proportion to the load transmitted through the scale column without the use of

Fig. 1—Above—Cutaway view of scale mechanism, showing its primary units, illustrates its simplicity of design and construction

special hand-filed cams, tricky adjustments to prevent backlash in engaged gears, or delicate adjustments of the angular relationship between sectors.

Basic motivation behind the new design was increasing realization that dial scales today cannot be delicate instruments which have to be babied. They are integral elements in heavy material handling systems, banged and battered in the rush of heavy production, even though high accuracies are expected of them. Many a scale platform becomes "aisle space" because of crowded plant conditions, and is traversed daily by shop trucks with heavy loads. Tremendous lateral shock is also common when trucks apply their brakes to stop on the platform.

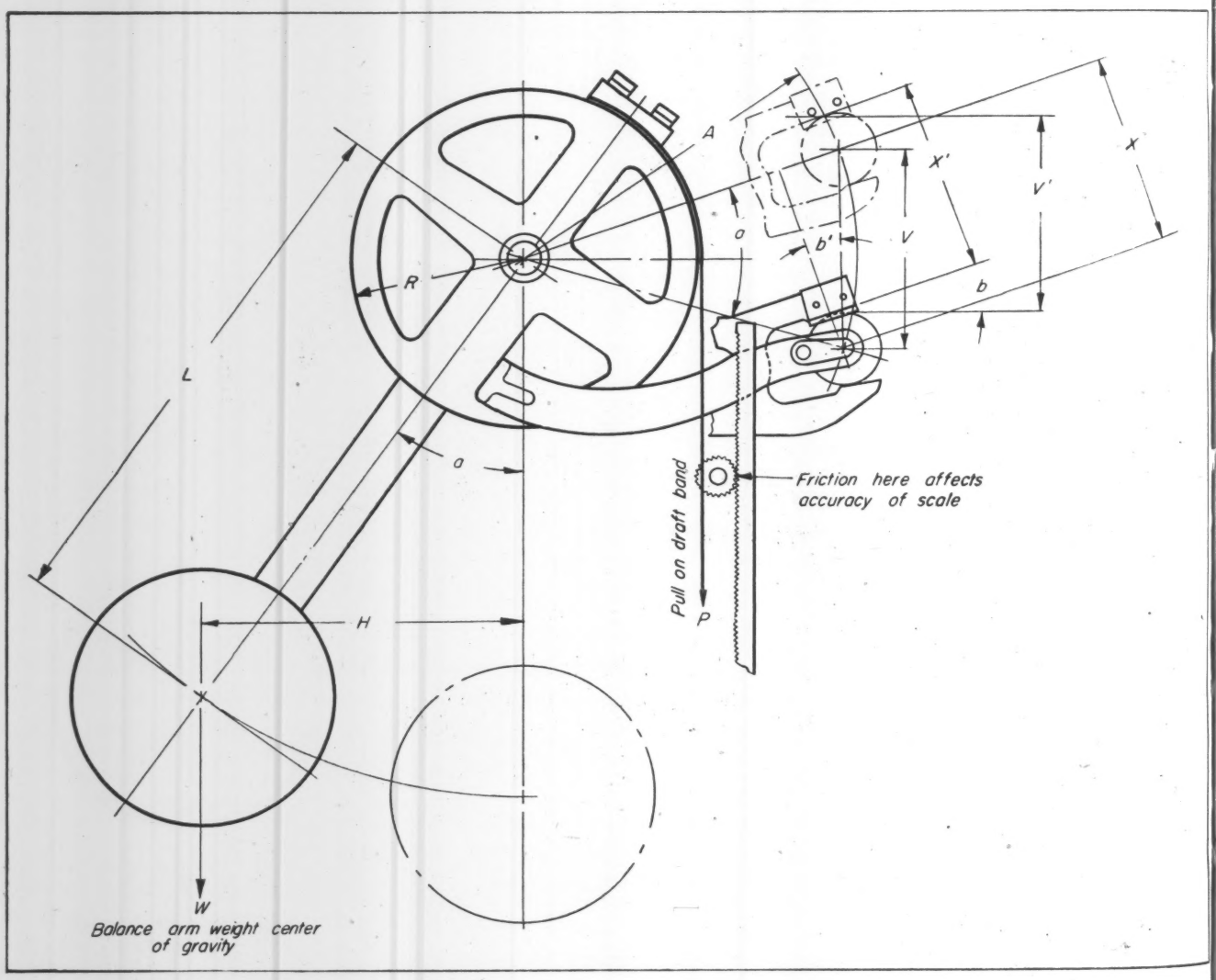
Three objectives guided the engineering of the new scale mechanism: (1) Absolute minimum of service and adjustment, (2) maximum durability in use, and (3) accuracy matching or exceeding anything found in the heavy-duty scale field today.

In the new mechanism, *Fig.* 1, to prevent creep, kinking and corrosion, and to maintain perfect flatness, the draft bands are of a special alloy. These bands draw down over the peripheries of circular cast iron drums. Fastened to each drum is a pendulum arm with its weight and, in addition, each drum has an integrally cast roller arm. The rollers at the ends of these arms engage right and left yokes of a floating plate which carries a stainless steel rack and a mild-steel bar parallel thereto. This bar serves as the armature for an Alnico magnet which is located directly in line with the pinion on the dial pointer shaft. Thus the rack assembly is kept in constant and complete engagement with a light, even pressure on the pinion. There is, of course, a dashpot for the rack assembly to minimize drift and oscillation, and to provide quick, sure pointer action.

Geometry of the linear relationship between the load on the draft band and the vertical movement of the rack is illustrated in *Fig.* 2. Angle of the yoke bearing surface with respect to horizontal, *b*, is constant because of the equal and opposed action of the two drum and roller assemblies. Further, this yoke bearing surface is parallel to a line between the center of the roller riding in the yoke and the center of the drum when there is no load upon the scale. At this time there is no pull down upon the draft band and the balance arm and weight are hanging vertically below the drum.

Since the moment of the pull upon the draft band around the drum center, *PR*, must equal the moment

Fig. 2—Linear relationship between load on draft band and vertical rack movement is illustrated by this diagram



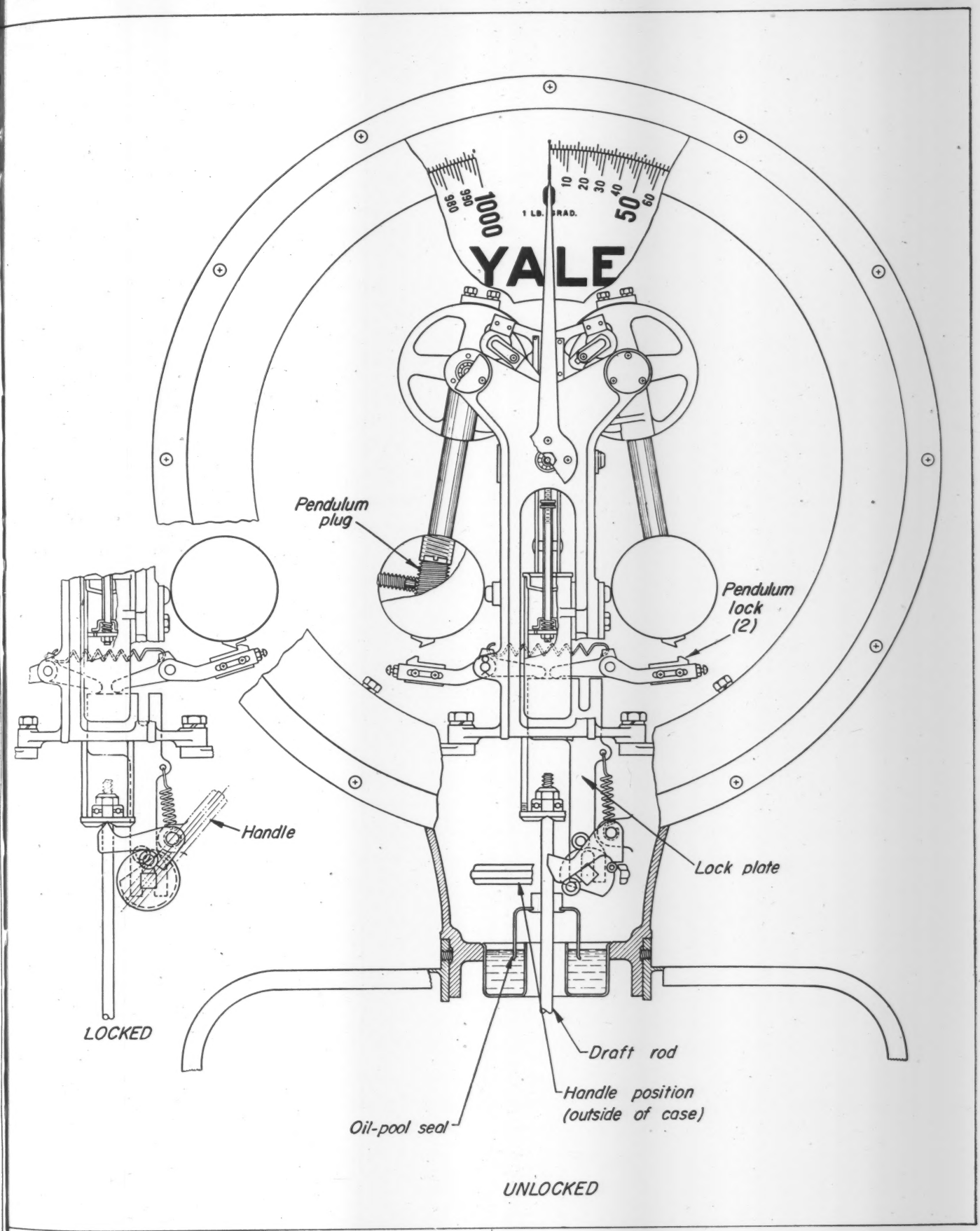


Fig. 3—Drawing shows locking mechanism in locked and unlocked positions. This mechanism not only locks pendulum weights in down position, but lifts weight of load on platform off the draft bands

of the lifted weight, PR is proportional to WH or $WL \sin a$. Also, since b is constant, there is a fixed relationship between V and X, or V' and X'. Further, by simple geometry it can be shown that $X = A \sin a$, and that X, therefore, bears an exact linear relationship to $L \sin a$, or H. Accordingly, V bears an exact linear relationship to H. Therefore, V is directly proportional to WH (W being constant), which is, as originally shown, exactly proportional to the pull on the draft band, P. Other dial scale mechanisms usually employ cams which must be hand filed to achieve this linearity, the angular relationship between cams and sectors must be manipulated, or floating cam members are involved.

Two Service Adjustments Required

From a service standpoint, adjustment of the scale mechanism is simple and ingenious. Only two adjustments are involved and neither can go out of adjustment easily in service. First, the ratio adjustment in any dial scale is made by pendulum length. An interesting point in the Yale design is the use of a plug in the pendulum weight, *Fig.* 3, so that only it and not the whole pendulum need be adjusted to shift the center of gravity of the massive element. In this manner, a vernier control is provided on the ratio adjustment. Second, pointer balancing is achieved in both directions at the pointer hub by means of lateral and vertical screws, thus compensating for any minute eccentricity of the pointer pinion. This principle is common to most good, modern dial scales.

Cast iron is used for the drums and the main frame to insure dimensional stability. Die castings, cast aluminum, and brass have been tried and found wanting. All parts which are not stainless steel or brass are heavily cadmium plated for corrosion resistance. The weight arms, the rack, the pinion and the yoke plate are stainless steel. The rollers are brass, with a full 4-to-1 ratio between length and diameter at the surface of contact between roller and stationary roller pin. The roller hub is tapered so that there is only an 0.015-inch wide ring of contact between the roller hub and the roller retaining pads. Since the roller contact with the yoke is always at the top when weighing, the yoke clearance is not critical and the fit can be sufficiently loose to permit the roller to turn over and over with constant use so that it always presents a different point of contact with the yoke. This action tends to maintain roller roundness over a long period of time. The yoke bearing plate itself is nitrided for maximum hardness. If, after years of service, anything in the mechanism were to need replacement, it would be the brass roller.

The six ball bearings employed are painstakingly and interestingly handled. They are literally untouched by human hands from the plant of the bearing manufacturer through receiving, cleaning, testing, assembly, final scale shipment, and the entire scale life. While being tested for exacting friction limits, washed, dried, and lubricated with a hypodermic needle, the bearings are kept in an air conditioned room, and touched only with special tools and fixtures. Their precision is such that they match any industrially practicable knife edge, and give freedom from friction equivalent or superior thereto.

The locking mechanism on this new scale represents a significant advance in that it achieves two things in one motion: (1) It locks the pendulum weights in the down position and at the same time lifts the entire weight of the draft rod in the scale column, and the load on the platform, off the draft bands. This is accomplished by means of a handle-actuated lever which engages a V-notch in a heavy plate on the draft rod which connects to the load-carrying lever system. At the same time it allows a lock plate to drop which permits the two pendulum locks to be drawn by spring action into locking position.

With respect to accuracy, it is worthy of note that the static friction in the new design is so small and the principle of operation so simple, that it is possible to guarantee an accuracy of one part in 1000, and to achieve, in actuality, accuracy to the extent of one part in 2000. The same head and dial mechanism is used whether the complete scale is being designed for a capacity of 25 or 100,000 pounds. Capacity of the mechanism itself under direct loading without any lever system is 25 pounds and its application up to the largest industrial system (50 tons) is a matter of lever linkage.

Bright Future for Gas Turbine

MOST serious competitor of the diesel locomotive is the coal burning gas turbine locomotive. A 4000-horsepower coal burning locomotive gas turbine is now being constructed, and it is anticipated that fuel and maintenance costs will be lower than for any other locomotive ever built.

Expected fuel cost, when using coal, will be approximately one-half of that of a diesel locomotive of similar horsepower, and lubrication costs should not exceed one-tenth those of the diesel type. The purely rotary motion of the gas turbine will result in minimum maintenance and vibration. Several other gas turbines, of a design similar to that of the locomotive unit, have operated in oil refineries continuously for several years without shutdown.

There are other incentives for using coal besides reducing fuel costs. It is generally predicted that coal reserves will last about 3000 years as compared with 15 years for oil. Even if the latter figure is appreciably in error, the tremendous difference in favor of coal is evident.

Since no water is required in its operation, the gas turbine cycle should be particularly attractive for locomotive installations. Elimination of the now necessary water treating provisions for both diesel and steam locomotives should certainly be desirable. Furthermore, the large amount of excess air used in the gas turbine combustion process permits a clear stack free from smoke at all loads.—*From an address by Dr. J. T. Rattaliata, dean of engineering, Illinois Institute of Technology, at the recent Annual Indiana Coal Conference.*

MACHINE Editorial DESIGN

Increase Production through Design

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One of the most effective means of accomplishing such refinement in design is for engineers to become more and more cognizant of the latest available methods of production and to develop their machines with these continuously in mind. It has been proved time and again that otherwise good designers often fall down badly through neglecting to take into account the possibilities of economical and time-saving production processes. If, however, more engineers would devote a commensurate amount of time and effort to designing for production with that now taken up by designing for function, they unquestionably would come through with the same highly commendable results.

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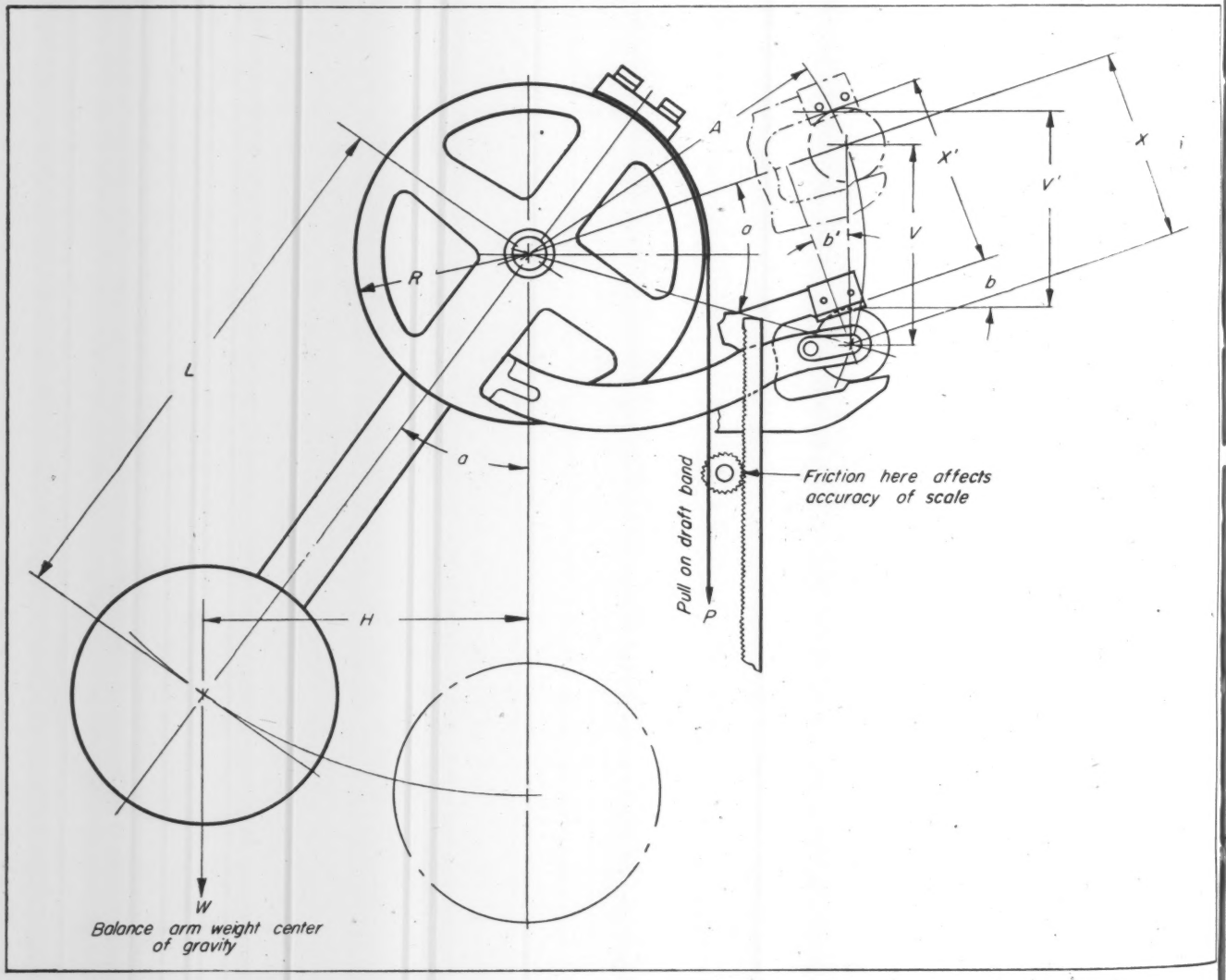

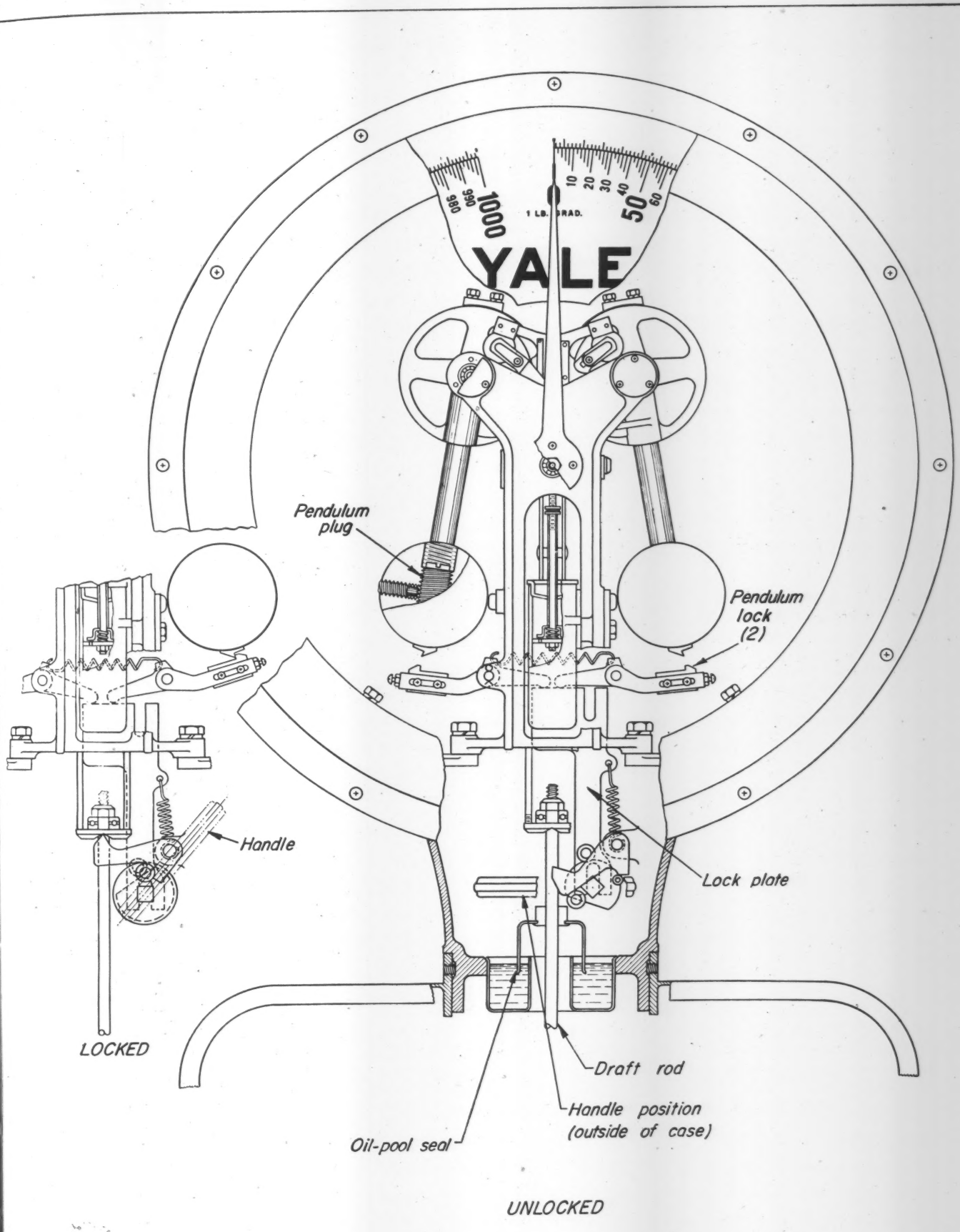

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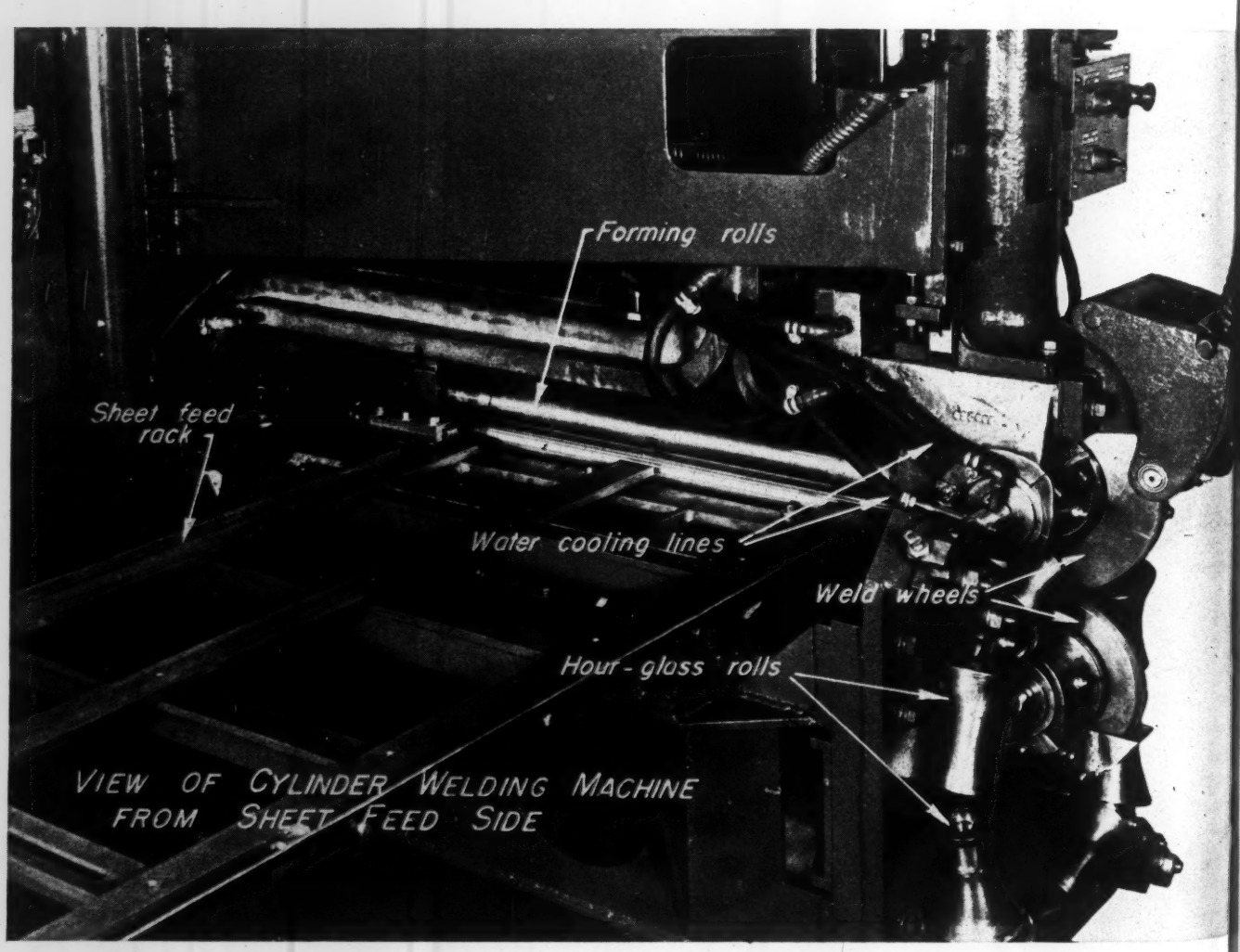
DESIGNS OF THE MONTH

Cylinders Formed, Welded Automatically

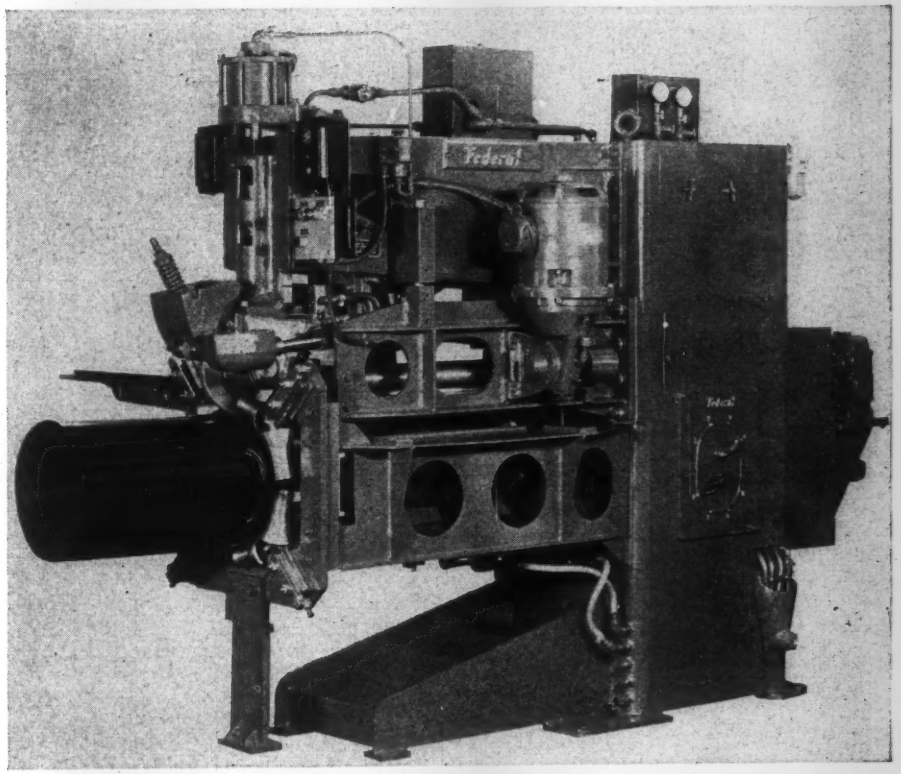
FUNCTION of the machine shown at the top of the following page, is to form flat sheet stock into cylinders, seam weld the cylinders and eject them automatically onto a conveyor or other handling equipment.

In operation, sheet stock is fed manually into a group of power-driven rollers (see below) which form the sheet into a cylinder the ends of which are held in proper lap position by a Z bar. Next, a pneumatically actuated "kicker" pushes the cylinder forward into the weld wheels. As the lap joint of the cylinder passes out through the power-driven weld wheels, welding takes place. As soon as one seam-welded cylinder clears the machine, another sheet may be fed into the rolls for forming and welding.

Weld wheels are frictionally driven by spring-loaded knurled wheels which in turn are driven through a gear-box, driveshafts, universal joints and gear reduction units by a constant-speed motor. The knurls not only drive the weld wheels but trim their edges to maintain correct contour. Vertical movement of the upper weld wheel to



VIEW OF CYLINDER WELDING MACHINE FROM SHEET FEED SIDE

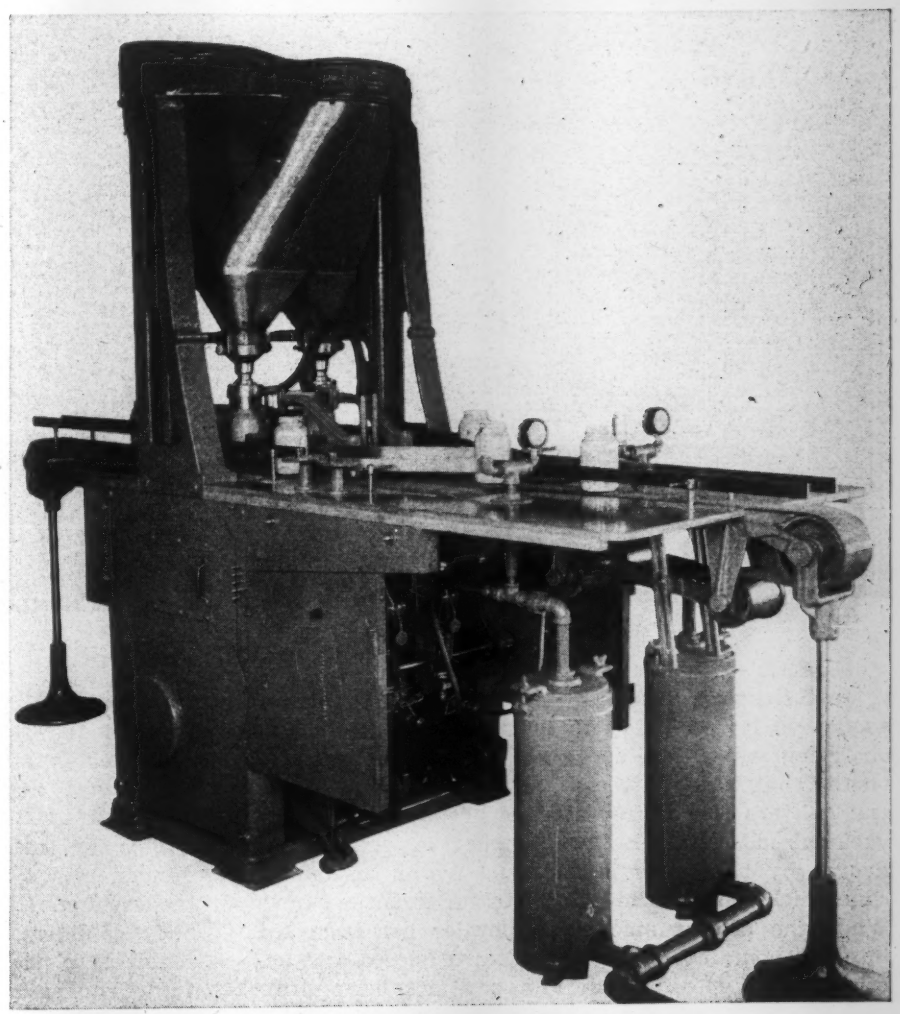


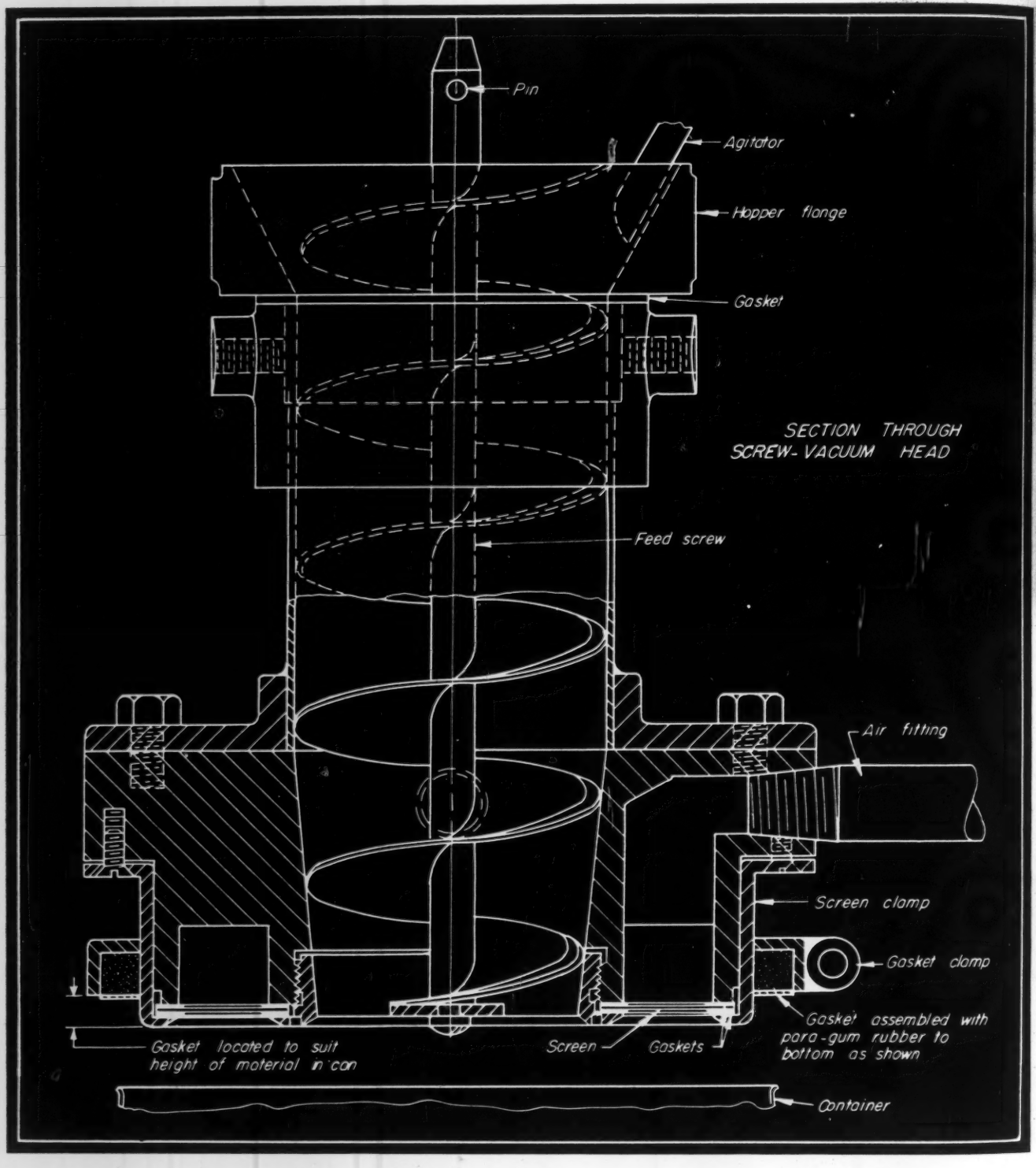
and away from the work is effected by an air cylinder controlled by a solenoid-operated air valve and foot switch. The "hour-glass" rolls, seen at the front of the machine, serve to guide the cylinder as it travels forward during welding. These rolls are adjustable to accommodate a range of tube sizes. Manufacturer: The Federal Machine & Welder Co., Warren, O.

Combines Screw Feed and Vacuum Filling

COMBINING screw feed and vacuum filling, a new unit, two of which are shown mounted on the machine, right, is particularly suitable for dry powdered products which require a certain amount of packing or compressing to fill a container, or for use where dust in the filling operation is to be avoided.

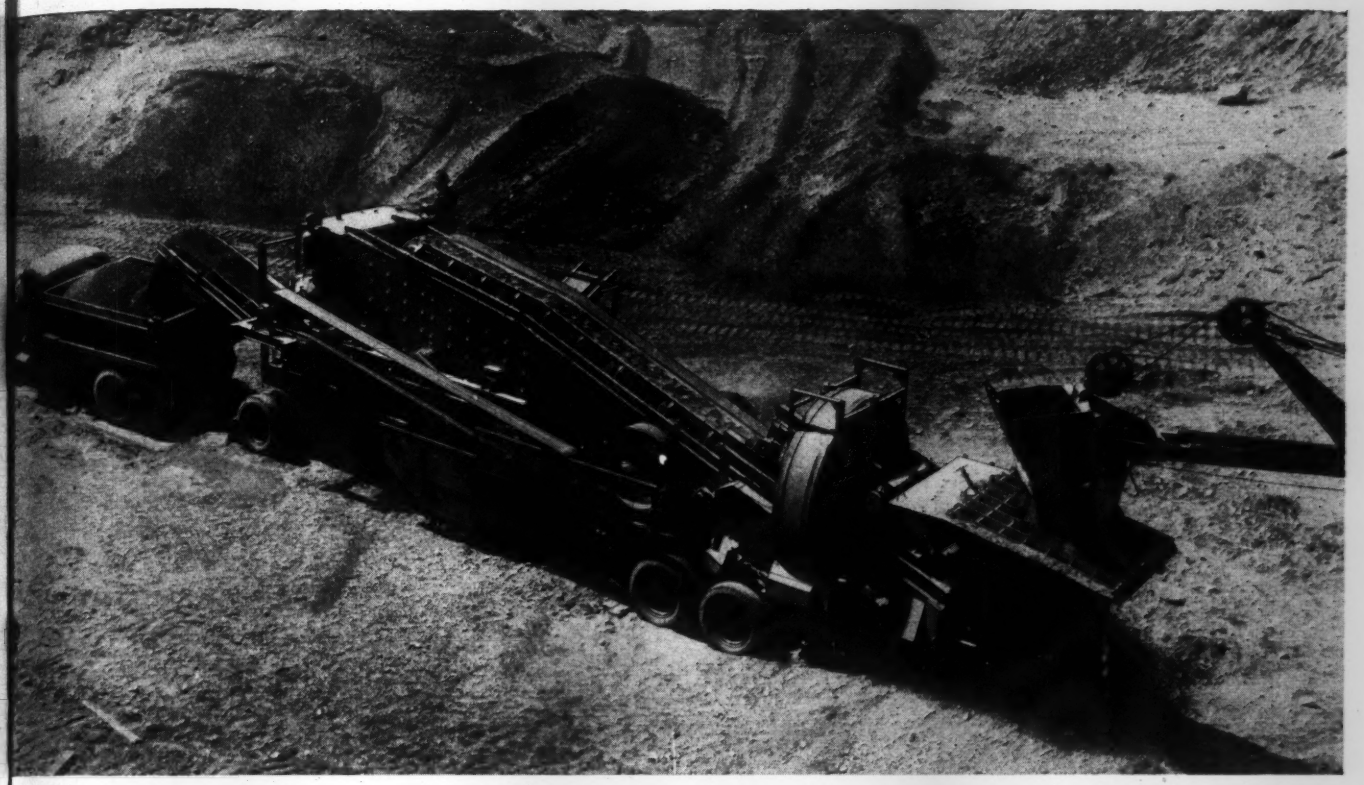
The unit consists of a combination screw-vacuum head (see blueprint, next page), a valve-control mechanism mounted on the cam shaft of the filling machine, a separate motor-driven vacuum pump, and a tank and filter. Degree of vacuum ranges from 15 to 28 inches, depending upon the size and style of the container, the amount of packing required, etc. In operation, the container is held up





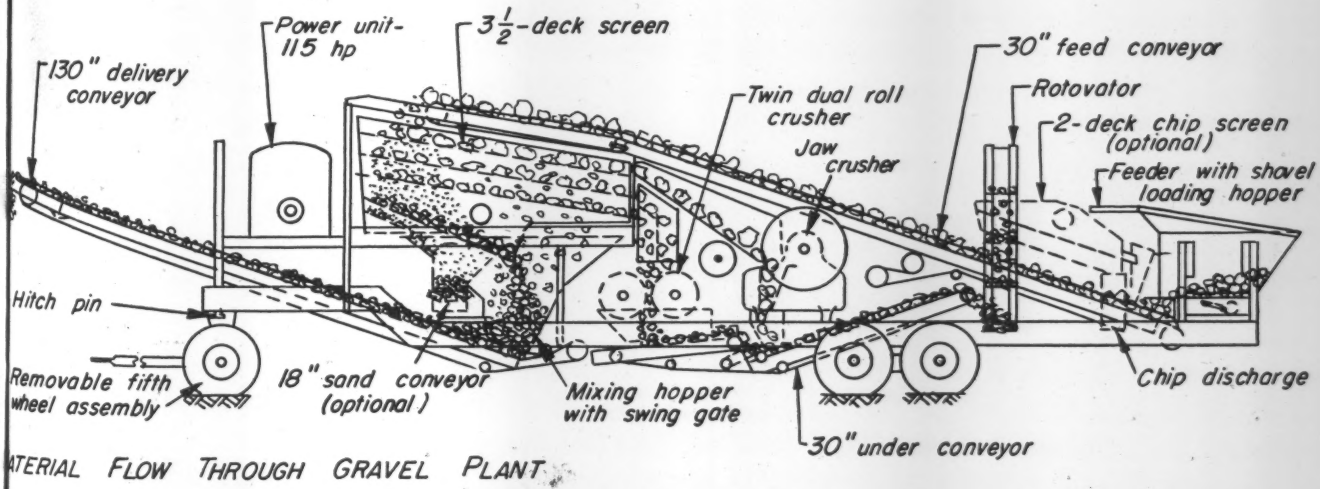
against the screw-vacuum head which has a rubber gasket on its periphery to insure a tight seal. The operating valve then opens and a vacuum is drawn on the container. At the same time, the screw starts and delivers the desired amount of powder into the vacuumized container. The amount of powder delivered by the screw is governed by an adjustable cam which controls the number of turns of the screw. When the desired amount of powder has been fed into the container, the vacuum valve closes and another valve opens which allows atmospheric pressure to enter through the vacuum head. This blows through the screen in the vacuum head while the container is still held up against the head, packs the powder and insures a clean head for the next fill.

This equipment is particularly suited for rigid containers, either metal or glass, which will withstand the vacuum. Other types of containers, such as fiber body canisters, etc., can be filled, but a shroud is required to prevent them from collapsing. Manufacturer: Stokes & Smith Co., Philadelphia 24.



Gravel Plant on Wheels

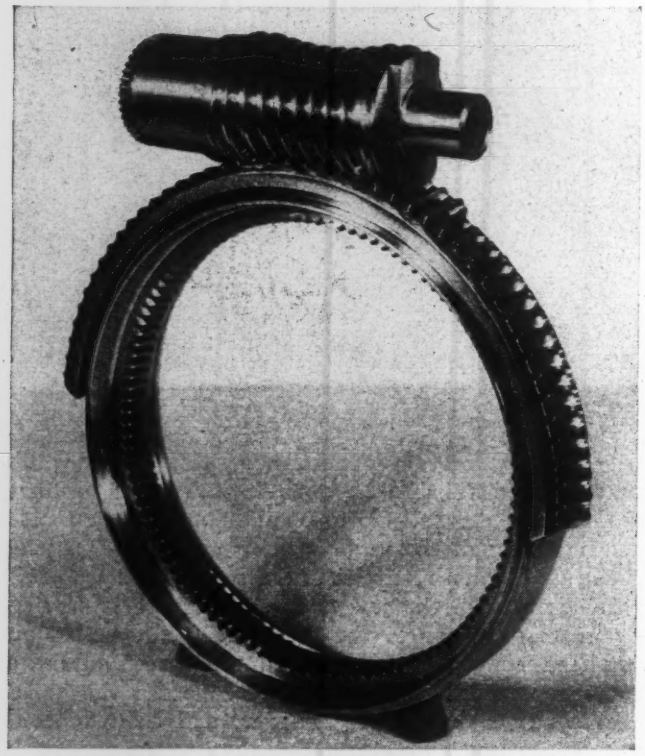
A COMPLETE gravel plant on wheels, the machine pictured above effects 3-stage crushing, screening and loading. As the sectional drawing, below, shows, pit material is delivered by shovel or dragline to the feed hopper, is plate fed to a 30-inch feed conveyor and carried to a 3½-deck screen. Material retained on the top deck goes to a jaw crusher. Material passing the top deck never reaches the jaw crusher to burden it with an excess of small aggregate. Material off the second deck is chuted to a wide-opening section of dual crushing rolls, while that off the third deck goes to the small-opening section of the rolls. Up to one-half of the aggregate passing through the large-opening rolls will pass the finish deck when returned to the screen. All material passing through the jaw and roll crushers is carried by under-conveyor to the "Rotovator", deposited on the feed conveyor, returned to the screen and the cycle repeated. Finished material passes the third deck, goes to the mixing hopper, and then by conveyor to a truck or bin. Sand passing the half-deck may be rejected or mixed in any proportion with finished material by use of a control gate. Mfr.: Universal Engineering Corp., Cedar Rapids, Iowa.



MATERIAL FLOW THROUGH GRAVEL PLANT

Applications

of engineering parts, materials and processes



Reduces Mechanism Size

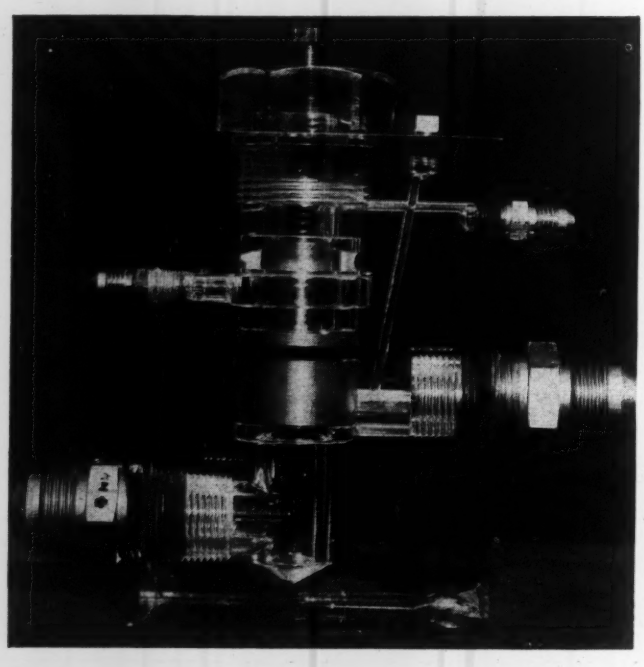
WEIGHT and size reductions in the Curtiss-Wright electric feathering propeller have been achieved by use of Cone-Drive double-enveloping gearing, seen left. Employed to adjust propeller-blade pitch, the gear set transmits output torques up to 65,000 lb-in., yet has a pinion measuring only 2-1/16-inches in diameter.

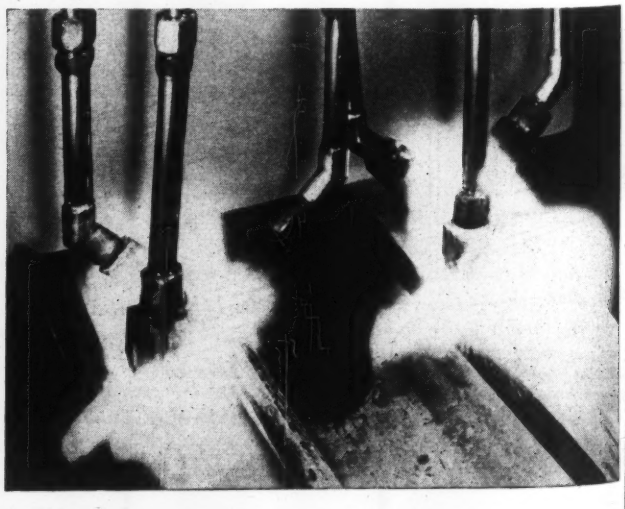
Facilitates Analysis

PROBLEM of studying fluid flow and poppet action of a pilot-operated constant pressure drop valve was solved by making the test model, left below, of clear plastic. This study unit, made by Brown Pattern Works, is impervious to water and oil, withstands 300 psi pressure and meets production tolerances of the final unit.

Provides Hardness with Oil Retention

FLAME hardening is used on the ways of the Monarch lathe to produce a surface that is wear resistant, yet has good oil retention. The nickel-iron way castings, below, are ground after hardening to 70-72 Shore; result is a hard martensitic wearing surface blended into a tough underbody of pearlitic iron. Since the pearlitic graphite is retained in the ground surface, a multitude of microscopic reservoirs is provided for retention of lubricant.





Intermittent Mechanisms

By Guy J. Talbourdet
Research Division
United Shoe Machinery Corp.
Beverly, Mass.

Part III

WHEN it is desired to incorporate a dwell period in the output motion of an intermittent mechanism a cam control may be employed to modify the motion of the cage in the basic planetary system. Two designs employing this principle are discussed and equations are presented for the input and output motions. Another type of mechanism, using a screw gear and cam control, may be employed to produce a similar result and also is described.

D. Internal Planetary Gear System with Rack or Segment and Cam Control Mechanism

As shown in *Figs.* 16 and 17, this mechanism is similar to the internal planetary gear system with rack and scotch yoke mechanism (*Figs.* 5 and 6) except that the scotch yoke is replaced by a cam and a radial cam follower.

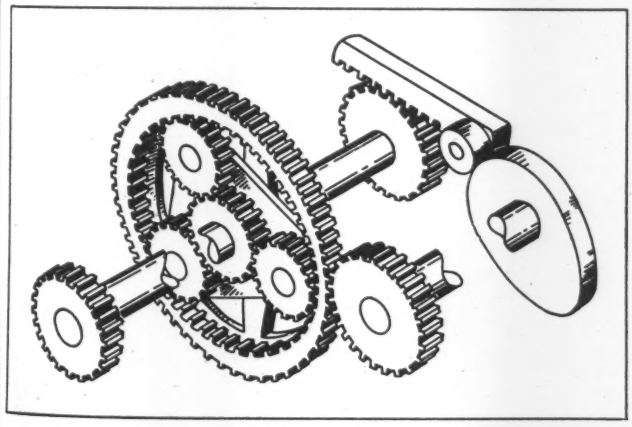


Fig. 16—Perspective view of internal planetary gear system with rack and cam control mechanism

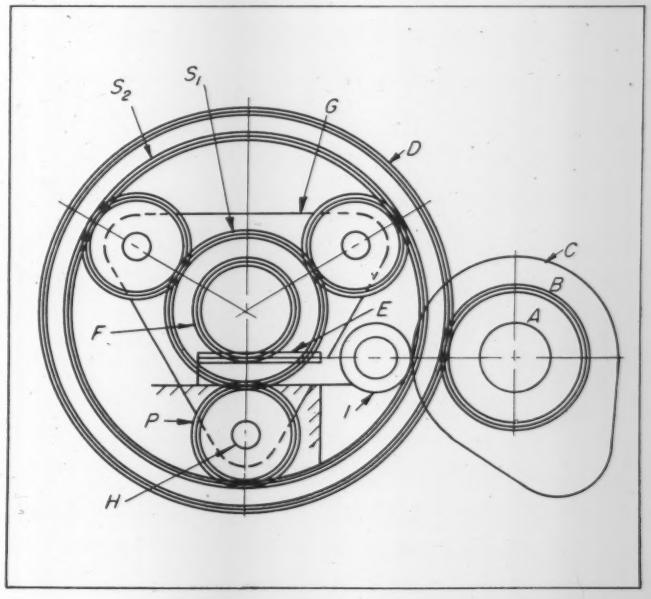
Mounted on driveshaft A are gear B and cam C. Gear B meshes with gear D which is integral with internal gear S_2 of a planetary gear unit, while cam C, through its radial follower I, actuates rack E which is in mesh with gear F. Gear F is fastened to cage G, carrying planet pinions P free to rotate on pins H mounted on G. Planet pinions P also engage with internal sun gear S_2 and output sun pinion S_1.

Here again is a simple internal planetary system in which the internal gear S_2 is the driving member rotating at a uniform velocity, while the motion of the center of the planet pinion is controlled by that of a cam follower.

By varying the motion characteristics of the cam follower, the motion of the output sun pinion can be made to meet some specific conditions, such as to remain at rest during a given angular displacement of the driving member, then to rotate a definite amount during the remaining part of the cycle of the driving member while fulfilling the zero acceleration conditions at the start and end of its motion. While many other conditions can be obtained, such as reversal of the motion of the output sun pinion, the following analysis will only consider the first conditions mentioned, that is, a definite rest period followed by a rotation of the output pinion during the remaining part of the cam cycle.

ANALYSIS: When θ_1 = angular displacement of cam during rest period of output sun pinion; θ_2 =

Fig. 17—Below—Schematic drawing of the mechanism shown in Fig. 16, which employs rack and cam control



This is the concluding data sheet of a series based on the author's recent ASME paper.

angular displacement of cam during motion of output sun pinion; K = ratio between a complete cam cycle and its angular displacement required to rotate sun gear S_1 a desired amount; and all the other symbols are as before, the equations of motion are as follows:

Motion of output sun pinion:

$$\theta_{s1} = m_1 m_2 \left[K(\theta - \theta_1) - \sin K(\theta - \theta_1)\right]$$

$$\omega_{s1} = m_1 m_2 K\omega \left[1 - \cos K(\theta - \theta_1)\right]$$

$$\alpha_{s1} = m_1 m_2 K^2\omega^2 \sin K(\theta - \theta_1)$$

where θ varies from θ_1 to 2π.

Motion of cage during dwell:

$$\theta_A = \frac{-m_1 m_2 \theta}{m_2 + 1}$$

$$\omega_A = \frac{-m_1 m_2}{m_2 + 1}\omega$$

$$\alpha_A = 0$$

where θ varies from O to θ_1.

Motion of cage when output sun pinion is moving:

$$\theta_A = \frac{m_1 m_2}{m_2 + 1}\left[(\theta - \theta_1)(K - 1) - \sin K(\theta - \theta_1)\right]$$

$$\omega_A = \frac{m_1 m_2}{m_2 + 1}\omega\left\{K[1 - \cos K(\theta - \theta_1)] - 1\right\}$$

$$\alpha_A = \frac{m_1 m_2}{m_2 + 1}K^2\omega^2 \sin K(\theta - \theta_1)$$

where θ varies from θ_1 to 2π.

Motion of rack and radial cam follower

$$S_R = R_F\theta_A$$

$$V_R = R_F\omega_A$$

$$a_R = R_F\alpha_A$$

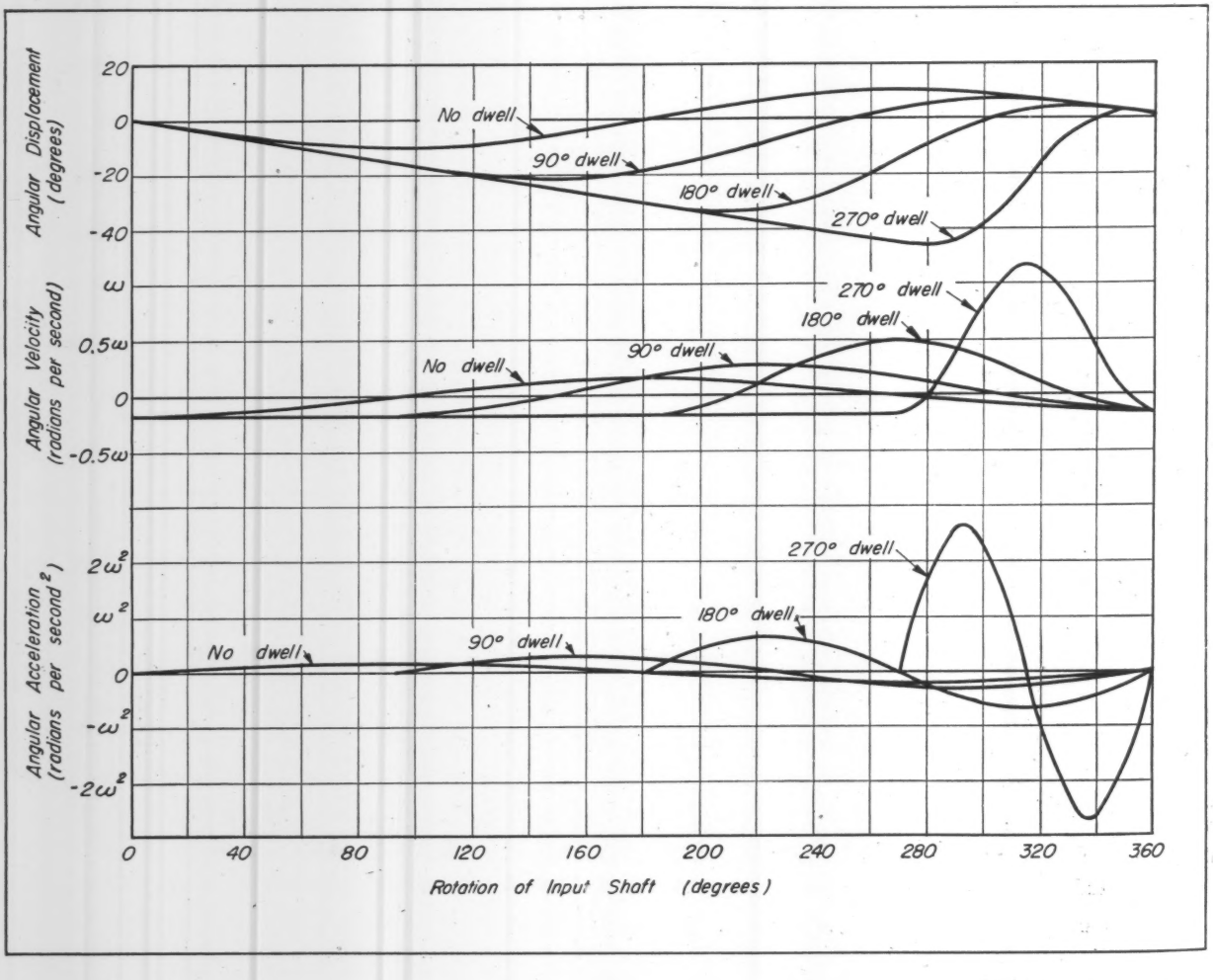
where R_F = radius of gear F.

In applying the foregoing equations the angles θ and θ_1 should be expressed in radians. To convert θ_{s1} and θ_A to degrees, multiply by $180/\pi$.

The radius vector of the cam is readily obtained from S_R for any value of θ during either the dwell period O to θ_1 or during the period when the output sun pinion is rotating.

To illustrate the motions of the cage and of the output sun pinion under conditions of no dwell (K = 1), 90-degree dwell (K = 1 1/3), 180-degree dwell (K = 2), and 270-degree dwell (K = 4) of the out-

Fig. 18—Motion of planet cage for internal planetary system with rack and cam control mechanism



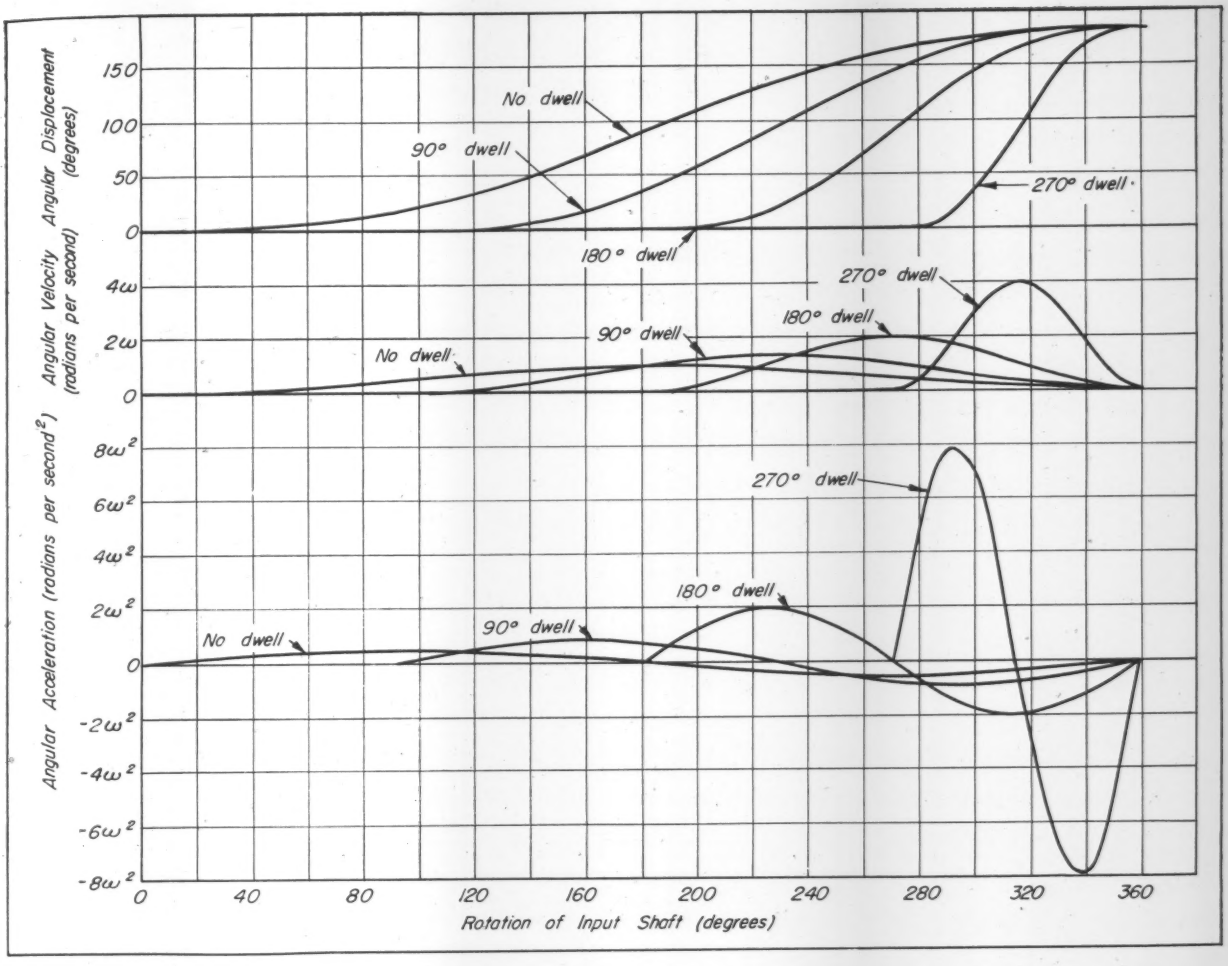


Fig. 19—Above—Motion of output sun pinion for internal planetary system with rack and cam control mechanism

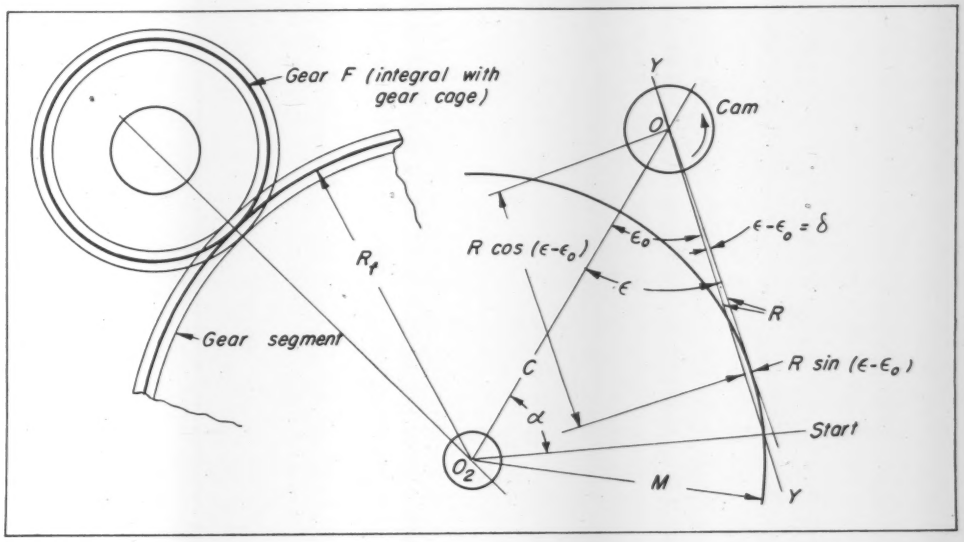


Fig. 20—Right—Layout for determining radius vector of cam when a gear segment and oscillating follower are used instead of the rack and radial follower shown in Figs. 16 and 17

put pinion, the angular displacements, velocities and accelerations are plotted in *Figs.* 18 and 19 for gear ratios $m_1 = N_B/N_D = 1/4$ and $m_2 = N_{s2}/N_{s1} = 2$.

Gear Segment and Oscillating Follower

In place of a rack and radial cam, a segmental gear and an oscillating cam follower can be used. For the same output motion the cam profile will be different from the foregoing. The following equation gives the radius vector, R, required for the manufacture of the cam (see *Fig.* 20);

$$R = \sqrt{M^2 + C^2 - 2CM \cos(\alpha - \theta_f)}$$

where M = length of follower arm, inches; C = center distance OO_2 between cam and swinging cam follower, inches; α = angle between OO_2 and radius vector when cam follower is at its extreme outward position, degrees; and θ_f = angular displacement of

segmental gear and swinging cam follower.

Co-ordinates of the radius vector, taking O as origin and the extreme outward position of the radius vector as the y-axis, are given by

$$x = R \sin \alpha$$

$$y = R \cos \alpha$$

where $\delta = \epsilon - \epsilon_0$ (*Fig.* 20) ϵ being any angle between OO_2 and the radius vector and ϵ_0 being this angle when the follower is at its extreme outward position. The angle ϵ is given by the relation

$$\cos \varepsilon = \frac{R^2 + C^2 - M^2}{2RC}$$

The equations of motion of the gear segment are as follows:

$$\theta_f = \frac{R_F}{R_f} \theta_A$$

$$\omega_f = \frac{R_F}{R_f} \omega_A$$

$$\alpha_f = \frac{R_F}{R_f} \alpha_A$$

where R_f = pitch radius of gear segment, inches.

E. Screw and Gear with Cam Control Mechanism

As shown in *Figs.* 21 and 22, the mechanism consists of screw B and cam C which are free to slide on input shaft A. The sliding motion is controlled by the action of cam C against a roll D fixed in the frame of the machine. Screw B is integral with cam C and engages output gear S_1.

Thus, the screw is subjected to two positive motions—a uniform angular rotation, and a variable axial translation. The combined motion of rotation and translation of the screw determines the characteristic motion of the output gear.

As with the mechanism previously described, the motion of the output gear can be made to meet some specific conditions. The following analysis will consider a definite rest period followed by a rotation of the output gear during the remaining part of the cam cycle.

ANALYSIS: In addition to the symbols already defined, the following notation applies to this mechanism:

θ_1 = Angular displacement of screw and cam during rest period of output gear
θ_2 = Angular displacement of screw and cam during motion of output gear
K = Ratio between one complete revolution of cam and the angular displacement required to rotate output gear a desired amount = $2\pi/\theta_2$
L = Lead of screw, in.
R = Pitch radius of output gear, in.
m = Ratio between number of starts in screw and number of teeth in gear = $L/2\pi R$
V = Uniform axial velocity of screw thread, in. per sec
S_a = Axial displacement of screw and cam, in.
V_a = Axial velocity of screw and cam, in. per sec
a = Axial acceleration of screw and cam, in. per sec²
S_o = Total axial displacement of screw and cam during rest period of output gear, in.

In the derivation of the following equations of motion it is assumed that the screw rotates clockwise and has a left-hand helix. Also, during the rotation phase of the output gear its angular acceleration is a sine function—the equations of motion being similar to those given in the analysis of the internal planetary gear system with rack and cam control mechanism discussed in the foregoing pages.

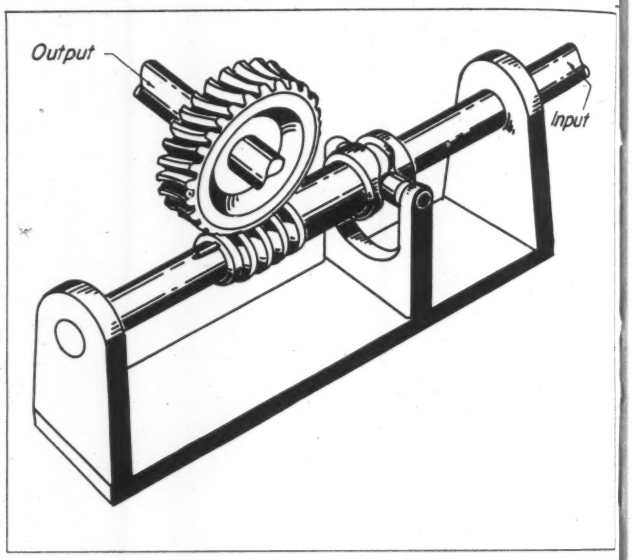
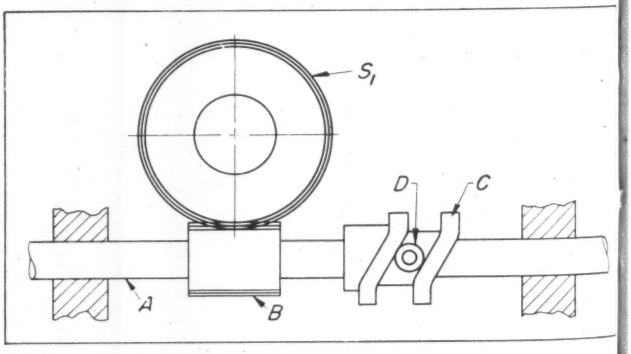


Fig. 21—Above—Perspective view of screw and gear with cam control mechanism, which can provide any dwell

Fg. 22—Below—Schematic drawing of screw and gear with cam control mechanism, also shown in Fig. 21



Motion of Output Gear:

$$\theta_{s1} = m\,[K(\theta - \theta_1) - \sin K(\theta - \theta_1)]$$

$$\omega_{s1} = mK\omega\,[1 - \cos K(\theta - \theta_1)]$$

$$\alpha_{s1} = mK^2\omega^2 \sin K(\theta - \theta_1)$$

where θ varies from θ_1 to 2π and $K = 2\pi/\theta_2$.

Axial Motion of Screw and Cam During Dwell Period:

$$S_a = -\frac{L\theta}{2\pi}$$

$$S_a = -\frac{L\theta_1}{2\pi}$$

$$V_a = -\frac{L\omega}{2\pi}$$

$$a = 0$$

where θ varies from 0 to θ_1.

Axial Motion of Screw and Cam During Motion of Output Gear:

$$S_a = mR\left[K(\theta - \theta_1) - \sin K(\theta - \theta_1)\right] - \frac{L}{2\pi}\theta$$

$$V_a = mRK\omega\left[1 - \cos K(\theta - \theta_1)\right] - \frac{L\omega}{2\pi}$$

$$a = mRK^2\omega^2 \sin K(\theta - \theta_1)$$

where θ varies from θ_1 to 2π and $K = 2\pi/\theta_2$.

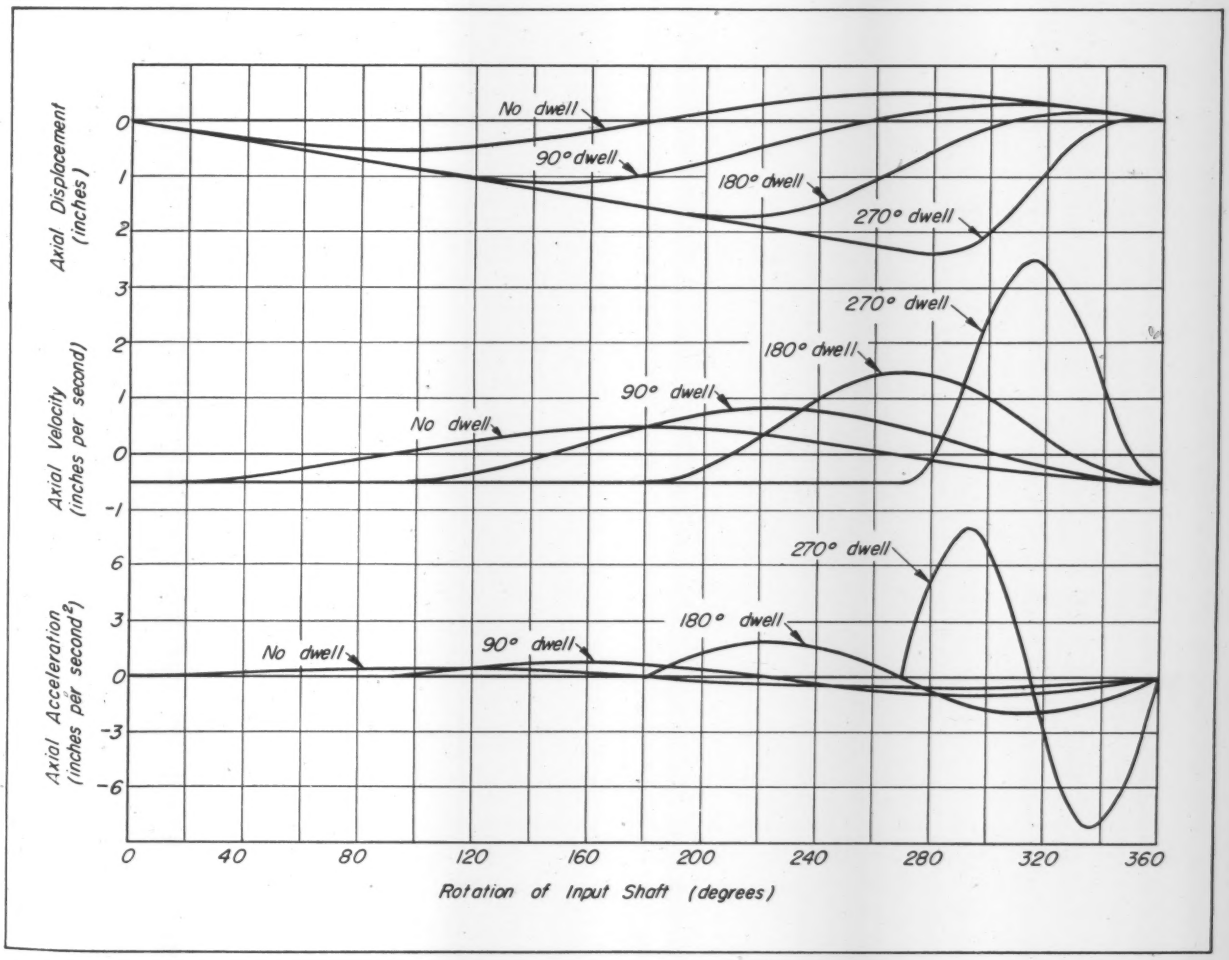
In applying the foregoing equations, θ and θ_1 should be expressed in radians. To convert θ_{s1} to degrees, multiply by $180/\pi$.

ENGINEERING DATA SHEET

Values required for the manufacture of the cylindrical cam are readily obtained from those of the axial displacement S_a of the screw and cam. To illustrate, the axial motion of screw and cam under conditions of no dwell, 90-degree dwell, 180-degree dwell, and 270-degree dwell of the output gear are plotted in *Fig.* 23 assuming gear ratio $m = \frac{1}{2}$ and $R = 1$ in. The same ratio is used in the calculations for the results plotted in *Figs.* 18 and 19. In this case, the motions of the output gear are the same as those of the output sun pinion plotted in *Fig.* 19. A comparison of *Figs.* 18 and 23 also shows the characteristics of the angular motion of the cage and the axial motion of the screw to be similar, i.e., the motion of the cam follower actuating the cage is the same as that of the cam actuating the screw. This type of mechanism is especially adapted for relatively high reduction ratio but the sliding action of the screw is not as favorable as the oscillating motion of the cage of the preceding device.

Although these data sheets have been concerned primarily with having zero acceleration at the start of the output member and zero deceleration at the end of its motion, many deviations from these conditions can be obtained. Specific requirements and conditions influence the choice for a given application.

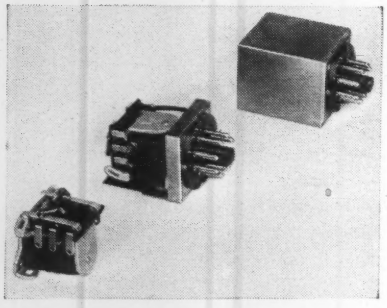
Fig. 23—Axial motion of screw and cam for the mechanism shown in Figs. 21 and 22



new parts and materials

For additional information on these new developments see Page 257

Miniature Relay



Small - size double - pole double-throw relays can be used on ac, dc or half-rectified ac. The units, identified as Type 118XBX, are rated 2 amperes at 115 volts ac. Normal dc operating power is 0.15 watts at the maximum coil resistance of 2200 ohms. The ac relays operate on approximately 9 va with coils rated up to 115 volts, at 60 cycles. Open type relays measure 1½ inches high by 1⅛ inches long and 1 inch wide and weigh 2 ounces. They can be enclosed in metal cases 1⅜ inches square and 1¾ inches high, equipped with vacuum tube type octal bases. They may also be hermetically sealed. Manufacturer: Struthers-Dunn Inc., 150 N. 13th St., Philadelphia 7.

For additional information circle MD 1 on Page 257

Rubber-Phenolic Plastic

New Hycar-phenolic compression-molding plastic has high shock resistance. This compound, designated G-E 12446, has the good moldability and heat resistance of the woodflour-filled phenolics and is strengthened by the resilient synthetic rubber. Impact resistance is therefore considerably higher than that of woodflour phenolics. Supplied as a powder for compression or transfer molding the plastic has low bulk factor and excellent pourability. It can be readily formed into complex parts having high finish. Manufacturer: General Electric Co., Plastics division, chemical dept., 1 Plastics Ave., Pittsfield, Mass.

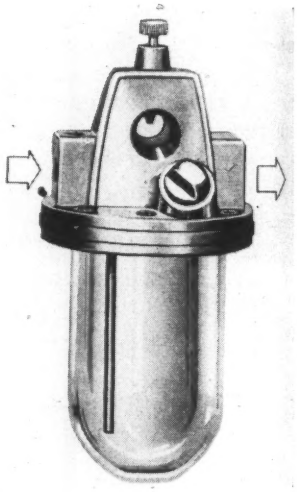
For additional information circle MD 2 on Page 257

Safety Solenoid Valve

Globe-type solenoid valve for 150 psi service, is designed for service in which valve is normally open. When an emergency arises, the control element causes the solenoid to become energized, thus closing the valve. Unit is designed to close with pressure and flow and it will remain closed as long as a pressure above 3 psi exists on the inlet side, irrespective of whether the solenoid is energized. For easy opening of the valve, a ⅛-inch bypass line and valve have been provided. Solenoid valve is made in six sizes from ¾-inch to 2½ inches. It may be used on 110, 220 or 440 volt, 60-cycle current, and is suitable for use with steam, water, gas or oil. Manufacturer: Johnson Corp., Three Rivers, Mich.

For additional information circle MD 3 on Page 257

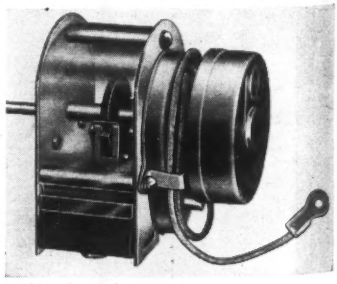
Air-Line Lubricator



Automatic lubricator is designed for installation on air lines serving pneumatic equipment; it meters oil into the air stream as a fine mist. Unit consists of a body, to which pipe connections are made, and a bowl containing a supply of lubricating oil. Flow of lubricant is controlled by a needle valve and is visible from both sides. Units, designated Series RL air-line lubricators, are made in ⅜ and ½-inch sizes and built of corrosion resistant materials. They are designed for use at pressures up to 150 psi. Manufacturer: Hannifin Corp., 1101 S. Kilbourn Ave., Chicago 24.

For additional information circle MD 4 on Page 257

Multi-Purpose Interval Timer

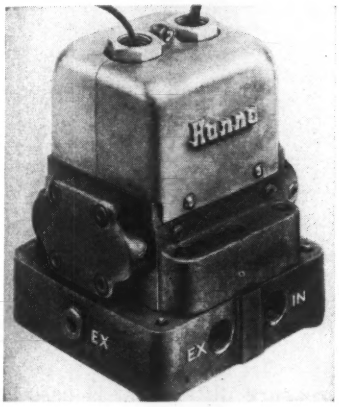


Series 8006 timers, available in two types, are made in a time range from one minute to over four hours. Type 003 is designed for applications where only one circuit and timing cycle are required. Timer motor and load are controlled by a single pair of contacts rated 25 amperes at 125 volts. Type 002, designed for applications where the timing cycle requires completion of one part of an operation before

another, or where heavier contacts are required to handle the controlled load, has a second switch rated ¼-hp at 125 volts. The other, lighter, switch is used for controlling timing motor and secondary load and is rated 20 amperes at 125 volts. Load switch opens 8 per cent of the total time interval before motor switch opens. Both models are furnished with a flattened cam-shaft extension for knob or dial mounting. Manufacturer: Haydon Mfg. Co. Inc., Torrington, Conn.

For additional information circle MD 5 on Page 257

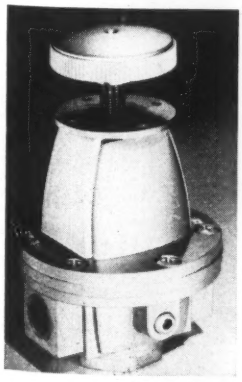
Four-Way Solenoid Control Valve



Balanced - spool type 4-way solenoid valve is controlled by a built-in pilot valve. Unit is so made that fluid lines may be connected to the accompanying manifold at bottom, or sides or a combination of both. Feature of the valve is its adaptability to straight line piping since valve capacity is equal to rated pipe size. Valves and manifolds are interchangeable and the valve proper may be removed from manifold without disconnecting the pipe lines. Solenoids may also be removed without severing wiring connections, provided a cord with pin plugs is used. Other features include low current consumption, short stroke, high operating speed and corrosion resistance. Manufacturer: Hanna Engineering Corp., 1765 Elston Ave., Chicago 22.

For additional information circle MD 6 on Page 257

Air-Pressure Regulators



Series PRD and LRD air-pressure regulators are made in ⅜ and ½-inch sizes for primary pressures up to 150 psi and secondary pressures from 5 to 125 psi. Type PRD is equipped with a flange for panel mounting where the adjusting knob extends through the front of an instrument board and the valve body remains in the rear of the panel. Types LRD is for installations where it is desirable to lock the adjusting knob against unauthorized change of setting. Locking is by means of a padlock passing through matching holes in two parallel disks. Feature of the regulators is the free-floating valve stem which makes it possible to back-off or reduce delivered pressure under dead end conditions by turning the adjusting knob. Manufacturer: Hannifin Corp., 1101 S. Kilbourne Ave., Chicago 24.

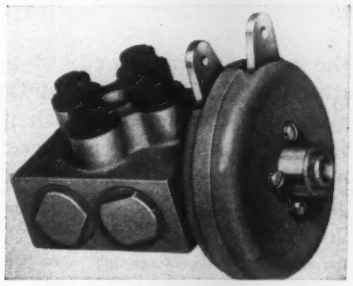
For additional information circle MD 7 on Page 257

Extreme-Pressure Lubricant

Powder type lubricant tradenamed Molykote consists of a molybdenum disulphide base powder. Suitable for high or low temperature applications the material can be used at bearing pressures of 100,000 psi without galling or seizing of the bearing surfaces. It is recommended for use at either high or low sliding velocities. Manufacturer: The Alpha Corp., Greenwich, Conn.

For additional information circle MD 8 on Page 257

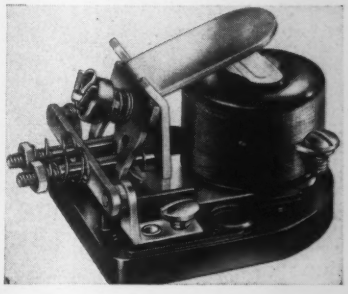
Follow-Up Selector Valve



Suitable for manual or automatic operation, the Electrol follow - up selector valve is designed for hydraulic systems. Typical applications are: Multiple brake actuation, furnace control, steering, and tool control. Unit is light in weight and is made in sizes to meet special requirements. Manufacturer: Electrol Inc., Kingston, N. Y.

For additional information circle MD 9 on Page 257

Motor-Starting Relays



Particularly applicable to use with capacitor - starting induction - run motors, the MS4A 3-hp motor - starting relay is suitable for use at voltages up to 230 ac. Of double-break construction, the relay is fitted with silver-cadmium oxide contacts and is provided with wide armature gap to give pull in at high voltage and snap-action drop out at low voltage. The units meet Underwriters Laboratories specifications, weigh 5 oz, and measure 2 11/16 by 2 1/16 by 1⅞ inches. They are mounted on bases of molded Bakelite. Styles are available with 800-ohm windings for use with 115-volt 60-cycle motors, or 2100-ohm coils for use with 230-volt motors. At normal adjustment, the 115-volt relay will open the starting circuit at 140

volts and close at 40 volts. The 230-volt relay pulls in at 275 volts and releases at 80 volts. Manufacturer: Potter & Brumfield Sales Co., 549 Washington Blvd., Chicago 6.

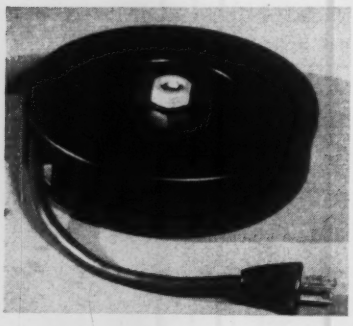
For additional information circle MD 10 on Page 257

Motor Starting Switches

Manual starting switches for use with fractional horsepower motors are furnished in five different types. These are: With general-purpose enclosure, without enclosure, combination motor-starting and selector switch, with cast-iron enclosure, and with hazardous-location enclosure. Feature of the units is the base which is made of a moisture-resisting, insulating material. This mounts and encloses the mechanism and contacts. Another feature is the action of the switch handle which moves to the off position on overload, thus giving a positive indication that the power is shut off. Manufacturer: General Electric Co., Schenectady 5, N. Y.

For additional information circle MD 11 on Page 257

Extension-Cord Reel



Suitable for use with portable and other equipment, Benjamin extension-cord reels are provided with up to 25 feet of retractable electric cord. Various models are made to suit specialized applications, differences being in the type of cord used, type of feed-in, or pig-tail, and use or nonuse of level wind attachment. Typical dimensions are 6 inches diameter and 1½ inches thick; typical weight is 2¾ lb. Manufacturer: Benjamin Reel Products Inc., 10700-10710 Broadway, Cleveland 5.

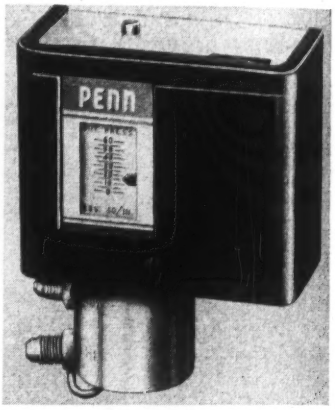
For additional information circle MD 12 on Page 257

Electronic Motor Speed Control

Rated at up to 3 hp, the Bulletin 105 electronic motor control will provide speed control of dc motors over a 60:1 range. The unit rectifies line current; speed changes are then controlled by a remote-located rheostat which may be placed at a convenient spot. Features of the unit are its ability to hold motor speed closely with changing load and to provide full torque over the complete control range. Manufacturer: J. B. Lewis & Co., 3324 Main St., Hartford 5, Conn.

For additional information circle MD 13 on Page 257

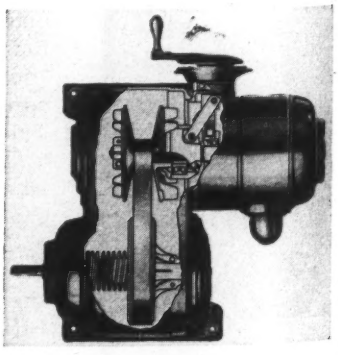
Differential-Pressure Switch



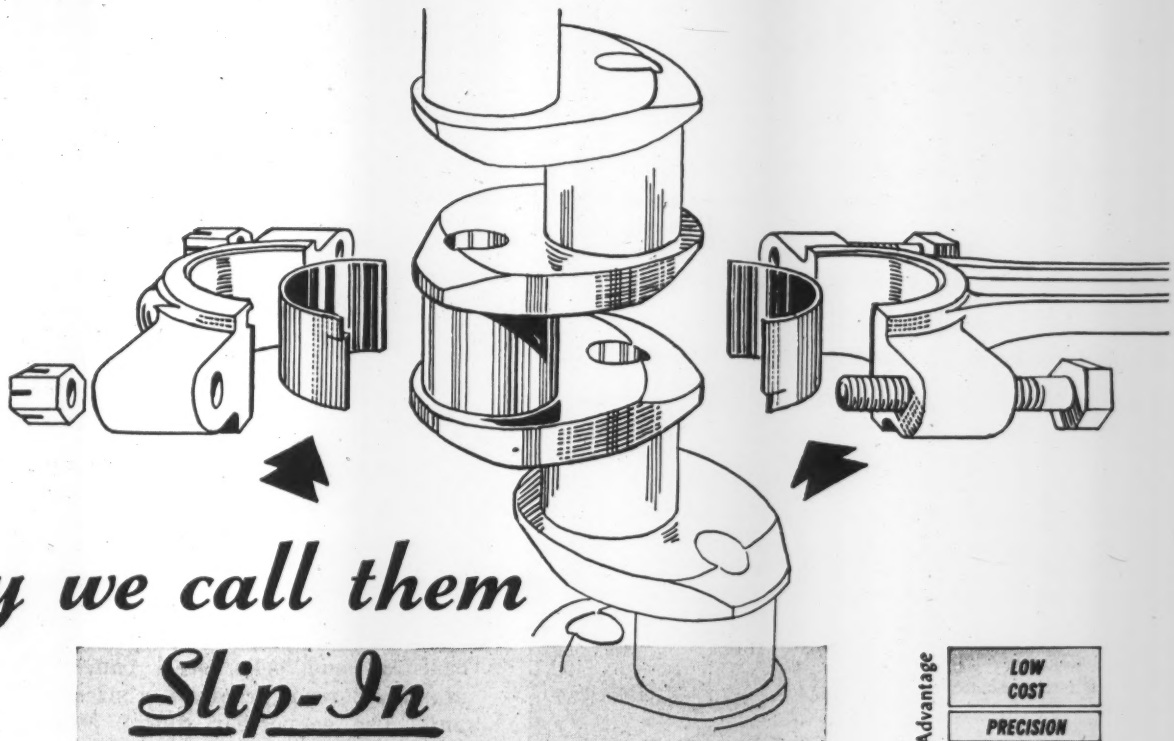
For use where two different pressures in a system must be maintained in proper balance, new differential-pressure switch can be used with pressures up to 225 psi. Unit uses a two-cavity bellows assembly in which the opposing pressures are directed against a single bellows. Force, equal to the bellows area times the pressure difference, is used to actuate a switch mechanism. Differential pressure necessary to alter position of the control contacts can be adjusted from 0 to 60 psi. Two types of switch mechanism are available; the first closes when the differential pressure decreases to the scale setting. Second type closes when differential pressure increases with respect to the scale setting. Automatic recycle or manual reset can be provided. Typical application is to provide automatic shutdown of refrigeration compressor when its lubrication pressure fails. Manufacturer: Penn Electric Switch Co., Goshen, Indiana.

For additional information circle MD 14 on Page 257

Variable-Speed Motors



Speed of a new line of motors may be varied through a 7:1 range. The units, which are available in ratings from ¼ to 50 hp, are made in styles including horizontal mounting and vertical mounting. Double-reduction gearmotor types are available in both styles. Control wheel, for manual operation, can be located on either side or above units; in vertical models the output shaft may be



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Johnson Bronze Sleeve Bearings Give You Every Worthwhile Advantage

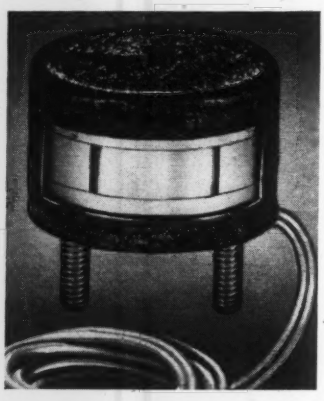
- LOW COST
- PRECISION
- QUIET
- LONG LIFE
- CORROSION RESISTANT
- UNIT CONSTRUCTION
- LOAD CARRYING CAPACITY
- HIGH RESISTANCE TO SHOCK
- LOW COEFFICIENT OF FRICTION
- EASY TO INSTALL
- CONFORMABILITY
- NATION WIDE SERVICE

JOHNSON BRONZE
SLEEVE BEARING HEADQUARTERS
BRANCHES IN 20 INDUSTRIAL CENTERS

positioned either high or low. A number of systems are provided for remote control of speed. A few of these are: Control shaft extension, chain and sprocket drive of control shaft, and shaft extension plus universal joint. Manufacturer: U. S. Electric Motors Inc., 200 E. Slauson Ave., Los Angeles 54.

For additional information circle MD 15 on Page 257

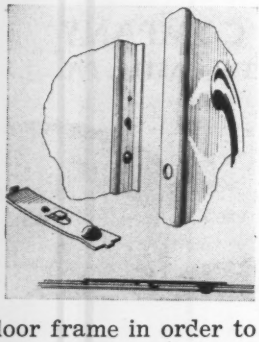
Magnetic Tape Recording Head



Model TD-704 recording head for use with magnetic tape recorders can be used for both recording and playback. It features high output, good frequency response, low hum level, and compactness. Head is used in high-impedance circuits with ¼-inch tapes and 0.20-inch track. Using tape with a coercive force of 300 oersteds at a speed of 7½ inches per second, the operating bias level at 40 kc is 1.7 milliamperes and the audio signal current for standard recording level is 0.15 milliamperes. Recording in this manner, the signal output from the high impedance playback winding is 5 millivolts. Impedance at 1000 cps is 1000 ohms. Overall dimensions of the unit are ⅞ by ⅞ by ⅝-inch deep. Manufacturer: Indiana Steel Products Co., Dept. A-34, 6 N. Michigan Ave., Chicago 2.

For additional information circle MD 16 on Page 257

Cabinet and Access-Door Latch

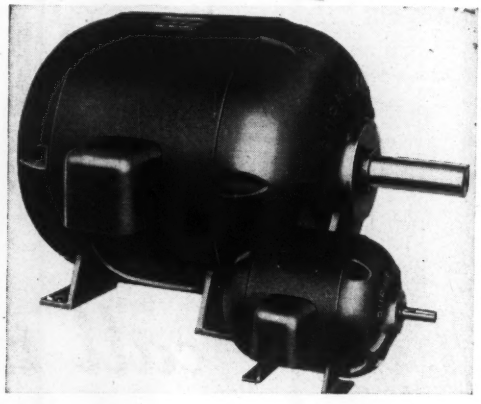


Simple latch for use with sheet-metal cabinet and access doors may be installed without the use of tools. Unit, known as the Speed Clip is a sheet-metal stamping. It is secured by snapping into place in three holes punched or drilled in the cabinet door. The detent bulb protrudes through one hole, engaging a recess in the door frame in order to latch the door. A lip on the clip engages a second hole and retains it, while a turn-down tab extends through the third hole and prevents the unit from twisting and becoming loose. Manufacturer: Tinnerman Products Inc., 2038 Fulton Road, Cleveland 13.

For additional information circle MD 17 on Page 257

Squirrel-Cage Induction Motors

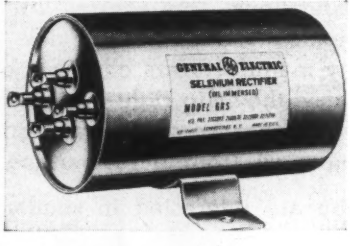
Available in frame sizes 203 to 505 and in frames larger than NEMA standard the Series D squirrel-cage induction motors are made in ratings from ½ to 55 hp. They are drip-proof units, fan cooled, air being induced through both end bells and exhausted through base. Features of the motors are use of



cast-iron end bells, steel baffles and frames, and aluminum rotor frames for sizes 203 to 365. Larger units use copper-bar rotors. Motors are made for speeds including 600, 720, 900, 1200, 1800 and 3600 rpm. Manufacturer: Burke Electric Co., 273 W. 12th St., Erie, Pa.

For additional information circle MD 18 on Page 257

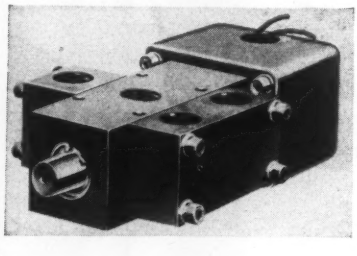
Oil-Immersed Selenium Rectifier Stacks



Oil-immersed selenium rectifier stacks resist the effects of moisture, fungus, salt air and corrosive vapors. Available in a large selection of ratings, the rectifiers feature sturdiness and high short-time overload due to increased thermal storage. Manufacturer: General Electric Co., Bridgeport 2, Conn.

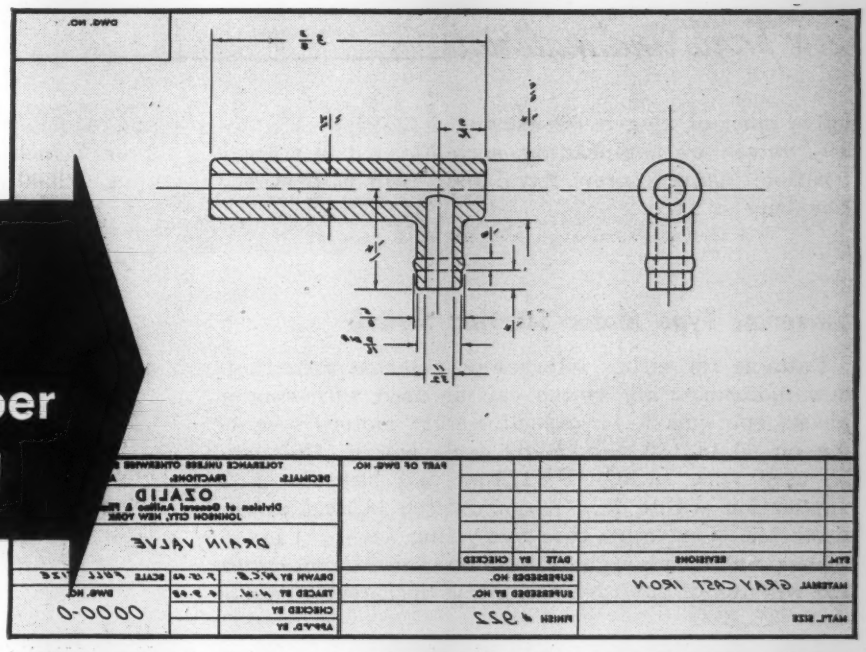
For additional information circle MD 19 on Page 257

Solenoid-Operated Selector Valves



Line of solenoid operated 4-way selector valves is designed for service with water, oil or air at pressures to 250 psi. They are made in pipe sizes of ¼, ⅜, ½, ¾ and 1 inch. Features of the new valves include simplicity, direct operation and fast, positive action. Shear-Seal principle is utilized in these valves. By this system metal-to-metal contact of sealing members wipes away foreign material and dust or other contaminants cannot hold

You're looking at the NEW intermediate paper for mass users!



The drawing above was reproduced on the new Ozalith Intermediate Paper. This duplicate paper original gives you Ozalid prints of maximum line density.

This New Ozalith Paper Costs Little—Has Great Mechanical Strength—Washable, Plastic Surface!

If your operation demands the duplication of a large bulk of drawings and plans, this new Ozalith Intermediate Paper should be of great interest to you.

For it is the answer to the need for a reasonably priced (7½¢ per square foot) paper duplicate original having maximum possible toughness of base; permanence, for filing and record use; and highest reprint quality. It reprints at exceptionally high machine speed.

No Tendency To "Bleed"

The dye image will not offset or transfer to other papers or tracings with which this new Ozalith paper has been placed in contact. There is no tendency to "bleed."

Ozalith is coated on a 100% rag base of great mechanical strength. It will not deteriorate appreciably with age. It is the most durable intermediate paper known.

Pen And Pencil Additions

You can wash Ozalith with a damp cloth —dust, dirt, and grease will come off quickly. Water will not cause the base to cockle or the image to run.

Pen or pencil additions can easily be made on either side of an Ozalith print. Because of its high transparency, contact prints should be made, and additions then made on the unsensitized surface.

Ozalith is a running mate to Ozacloth —but because of its low price, it is ideal for mass users. Write, today, if you would learn more about this and other Ozalid prints.

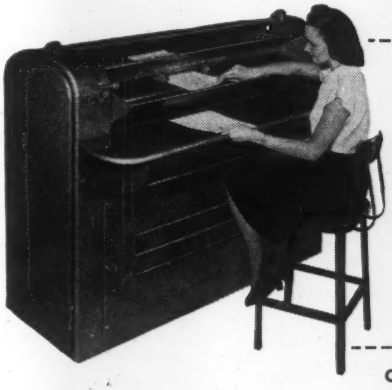
ALL OZALID PRINTS PRODUCED IN SAME MANNER

★ **No tie-ups when you shift from one type of print production to another. Simply choose your Ozalid material . . . and your Ozalid print-making machine exposes and dry develops it. Standard work prints are produced in 25 seconds.**

★ **Your drawings can be up to 42 inches wide, any length. Roll stock or cut sheets can be used. (Special machines accommodate 54" wide drawings.)**

★ **You—or anyone else—can be the operator. A few hours and you're an "expert."**

★ **See *all* the Ozalid prints you may make from any drawing . . . and learn full story. Mail coupon today.**



DEPT. NO. 193

OZALID ... A Division of General Aniline & Film Corp., Johnson City, New York

Gentlemen: Please send free copy of Ozalid Streamliner booklet illustrating all types of Ozalid prints.

Name_____ Position_____

Company_____

Address_____

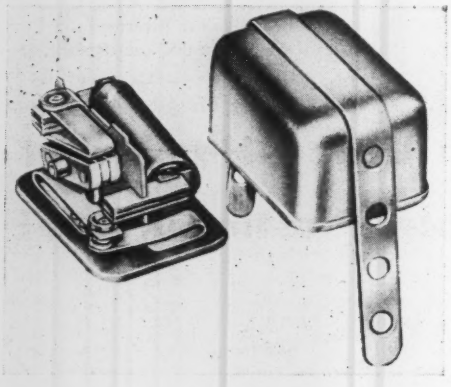
Ozalid in Canada—Hughes Owens Co., Ltd., Montreal

valve open or clog it. Measuring 7 13/16 by 5¼ by 3½, valves are two-position, spring-loaded in normal position. Manufacturer: Saval Inc., 1915 E. 51st St., Los Angeles 11.

For additional information circle MD 20 on Page 257

Universal Type Motor Starting Switch

Suitable for either internal or external mounting, new motor-starting switch can be used with single-phase, split-phase, or capacitor-start motors operating on 90 to 130 volt, 50-60 cycle power. Unit can be used with ratings to 1/3-hp and has universal application within this range. Switch is dust proof, protected by a brass case measuring 1⅛ by 1 11/16 inches and 1 inch high. It is connected in series with the winding of any type motor and operates by means



of the starting current. The starting circuit is opened between 1400 and 1500 rpm as the current drops. Precise opening speed can be obtained by means of an external resistance supplied with the unit. Manufacturer: Fitch, Allen & Co., 1131 Bryn Mawr Ave., Chicago 40.

For additional information circle MD 21 on Page 257

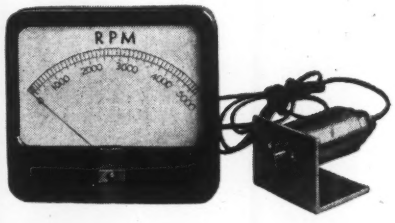
Abrasion-Resistant Enamel

Synthetic enamel known as Superclad has high acid and alkali resistance as well as excellent resistance to humidity, salt-spray and abrasion. A baking enamel, this finish was developed for applications in the same field as porcelain enamel. It has, for example, been successfully used for finishing washing machines. Manufacturer: Sherwin-Williams Co., 101 Prospect Ave., Cleveland 1.

For additional information circle MD 22 on Page 257

Electric Panel Tachometer

Suitable for continuous electric measurement of rotary speeds, new panel tachometer is accurate within ± 1 per cent of full scale deflection for any speed range. Tachometer consists of a pick up unit and a rectifier type meter with a D'Arsonval movement. Pick up is a generator with stationary armature and Alnico rotor. Meter can be furnished in either 3 or 7 inch size and is available in ranges 0-1250 rpm, 0-2500 rpm, and 0-5000 rpm. It can also be sup-



plied calibrated to such units as feet per minute or gallons per minute. Manufacturer: Crown Industrial Products Co., 1525 E. 53rd St., Chicago 15.

For additional information circle MD 23 on Page 257

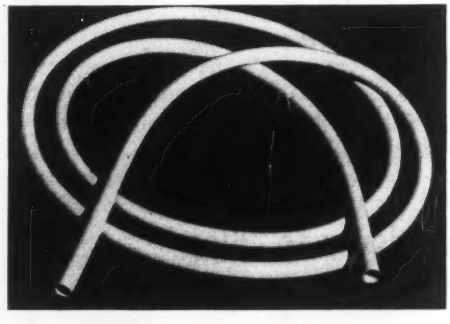
High-Strength Wire Cloth

Specification No. 4200 wire cloth equivalent to 200-mesh material is said to be seven times as strong as previous cloths. Made of Monel, brass or other metals it is long lived and retains its flatness. Manufacturer: Michigan Wire Cloth Co., 2100 Howard St., Detroit 16.

For additional information circle MD 24 on Page 257

Extruded Plastic Tubing

Thermoplastic tubing identified as Turbo REL-16-A will withstand operating temperatures up to 105 C in continuous service. It will retain its flexibility under



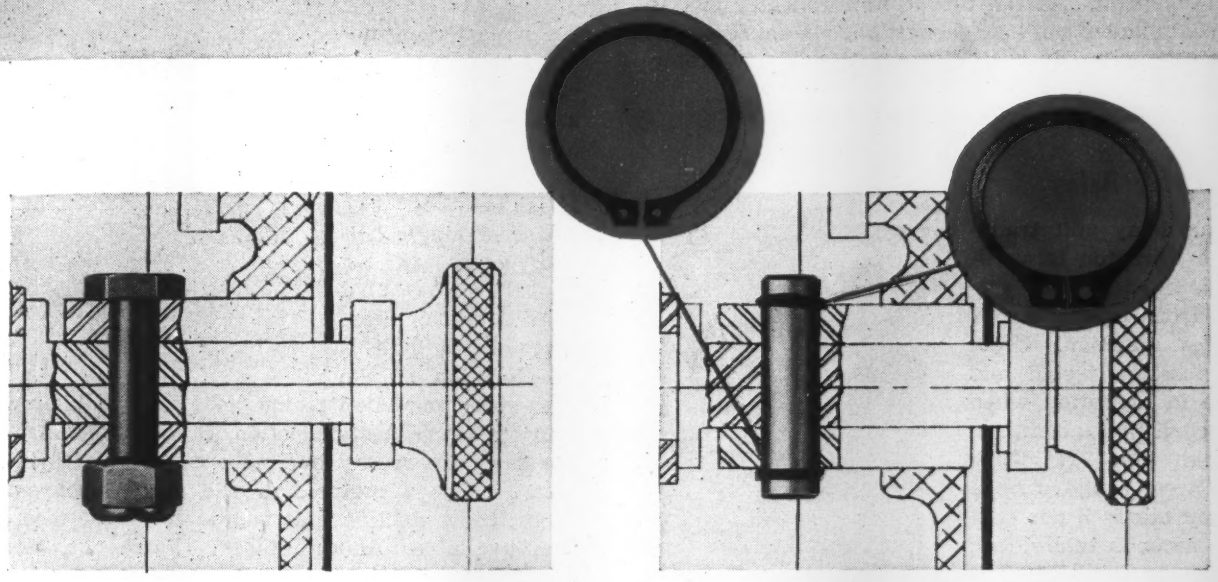
temperature cycling and withstand soldering and potting operations when serving as insulation. Manufacturer: William Brand & Co., 276 4th Ave., New York 10.

For additional information circle MD 25 on Page 257

Remote Control Unit

Torque control system for remote control of shaft or lever position to a high accuracy consists of three components: Transmitter, torque unit and amplifier. Positioning of the transmitter shaft results in precise duplication of its position by the torque unit shaft, with torque outputs increased from several gm-cm to several lb-ft. The transmitter shaft can be set manually or by elements sensitive to pressure, tem-

Truarc saves 5 minutes, 9 cents in materials per unit without re-design of electric sanders



OLD WAY

Special ¼" cap screw and ¼-28 fibre-insert nut holds idler arm and pulley assembly on Model A3 "Take-About" Sander, Porter-Cable Machine Company.

NEW WAY

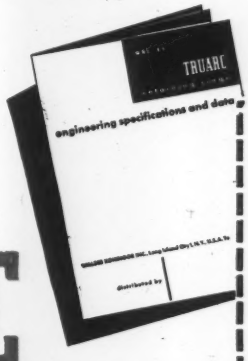
Simple ¼" C.R. shaft, grooved in automatic screw machine, equipped with Waldes Truarc Retaining Rings. Bowed external ring (#5101-25) at top exerts resilient pressure taken up by Standard external ring (#5100-25) at bottom. Assembly is secure against vibration, can be easily taken apart and re-installed many times with same Truarc rings.

Every sander through the production lines costs 9 cents less for materials, requires 5 minutes less labor —with just the simple change from cap screw and nut to Waldes Truarc rings by Porter-Cable Machine Company, Syracuse, New York. The change to Truarc required no new design, no alterations in castings, but just the reappraisal of old methods.

Truarc can help you cut costs and increase production, too. Wherever you use machined shoulders, nuts, bolts, snap rings, cotter pins—there's a Truarc ring that does a better job of holding parts together. All Waldes Truarc Retaining Rings are precision engineered, remain always circular to give a never-failing grip.

Send us your drawings. Waldes Truarc engineers will be glad to show how Truarc can help you.

See us at the Power Show, Grand Central Palace, N. Y.
November 29—December 4, Booths 522-523



WALDES
TRUARC
REG. U. S. PAT. OFF.
RETAINING RINGS
WALDES KOHINOOR, INC., LONG ISLAND CITY 1, NEW YORK

WALDES TRUARC RETAINING RINGS ARE PROTECTED BY U. S. PATS. 2,302,948; 2,026,454; 2,416,852 AND OTHER PATS. PEND.

Waldes Kohinoor, Inc., 47-10 Austel Place MD-11
Long Island City 1, N. Y.

Please send 28-page Data Book on Waldes Truarc Retaining Rings.

Name_____

Title_____

Company_____

Business Address_____

City_____ Zone____ State_____ ★

perature, volume, etc. and an amplifier provides the controlled power required to operate the torque unit. The entire control will operate from either single-phase, 110-volt, 60-cycle power or single-phase, 115-volt 400-cycle power. Maximum static error between the transmitter and the torque unit repeater is 0.15 per cent under no-load conditions. Manufacturer: Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.

For additional information circle MD 26 on Page 257

Time-Delay Relay

Time delay unit tradenamed Tarryton is available in models with settings from 1 second to 2 minutes duration. Units are vibration tested and stable in operation when subjected to acceleration as high as 12g. Time tolerances range from plus or minus 3 per cent for 5 seconds time delay, to plus or minus 10 per cent at 120 seconds delay in the temperature range of minus 65 F to plus 160 F. Units measure 2 11/16 inches long and 1¼ inches in diameter; they weigh 3 ounces. Manufacturer: Cook Electric Co., Diaphlex Div., 2700 N. Southport Ave., Chicago 14.

For additional information circle MD 27 on Page 257

Plastic-Covered Tubing

Armored tubing tradenamed Rub-Bub is electric-welded steel covered with a 1/32-inch coat of plastic. The material is suitable for use as guard rails as well as fluid lines; in the latter case the plastic coating serves as color coding. Advantages claimed for the tubing include coat permanence, toughness, and resistance to corrosive materials. Six standard colors in which coating is made are: Green, yellow, red, blue, brown and gray. Manufacturer: Samuel Moore & Co., Mantua, Ohio.

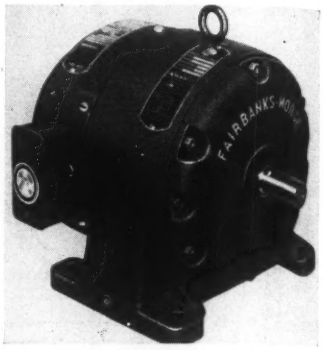
For additional information circle MD 28 on Page 257

Stainless-Steel Check Valves

Suitable for use with corrosive liquids and gases, the AMP check valve is of stainless construction throughout and uses soft rubber washer. Features of the new valve include a large seat area, self-washing seat design and low (6 lb) pressure drop. Two types of valves are made: One with a ⅜-inch NPT outlet and ⅝-inch 45-degree flare inlet, and another with ⅜-inch NPT outlet and ½-inch ¼-inch flat-flare inlet. Other sizes and threads from ¼-inch upwards are made on special order. Manufacturer: AMP Corp., 2921 Locust St., St. Louis.

For additional information circle MD 29 on Page 257

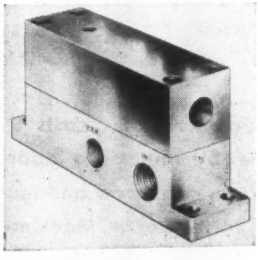
Axial Air Gap Motors



Compact gearmotors using motors of the "pancake" or axial - airgap type are now made in ¾ to 10 hp ratings. Units employ two ratios of single helical gears with hardened and shaved teeth. Feature of the line is the location of the high-speed reduction pinion close to a double-row ball bearing to reduce deflection to a minimum. Gear housings are sturdy one-piece castings with integral feet. Using a motor half the size of conventional types, the reduction unit is said to be the most compact available. Manufacturer: Fairbanks, Morse & Co., Chicago 5.

For additional information circle MD 30 on Page 257

Air-Control Valve



Air valve for three or four-way control of air cylinders uses a slide valve actuated by a balanced piston. Since the molded slide does all of the actual valving, the piston which moves the slide does not require precise fitting. The slide's flat sealing surface improves with use. Sizes available cover the range ¼ to 1 inch. Manufacturer: Valley Tool Co., 5515 E. Slauson Ave., Los Angeles 22.

For additional information circle MD 31 on Page 257

Water-White Plastic

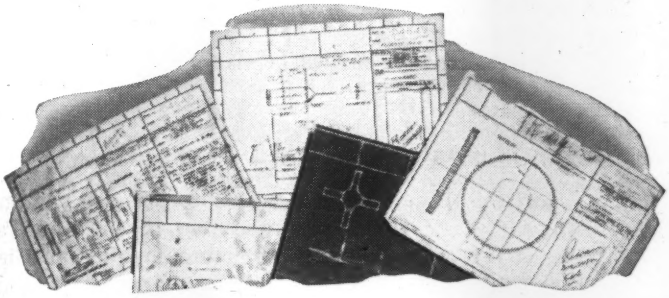
Availability of water-white cellulose acetate butyrate under the trade name Tenite II has recently been announced. The material is made in the optically clear form as well as in delicate tints which can be closely matched in separate lots. Manufacturer: Tennessee Eastman Corp., Kingsport, Tenn.

For additional information circle MD 32 on Page 257

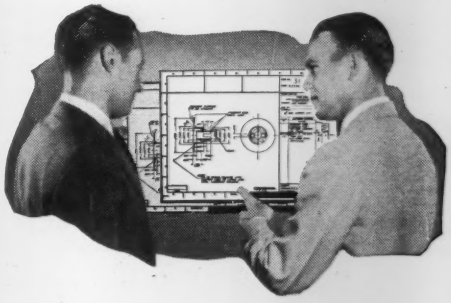
Cushioned Air Cylinders

Featuring the elimination of tie rods, new line of air cylinders has end caps which may be rotated independently without disturbing end seals. Piping is thus simplified and pressure losses in fittings reduced. Additional feature is adjustable cushion which

Get top-quality intermediates from every type of original with this one photographic paper



Reproduces "unprintables," opaque drawings, blueprints, direct process prints ...You'll like the way Kodagraph Autopositive Paper works—the way it gets sharp, clear, black-and-white intermediates or second originals from originals of every type—weak pencil tracings, opaque drawings, faded originals, blueprints, direct process prints.



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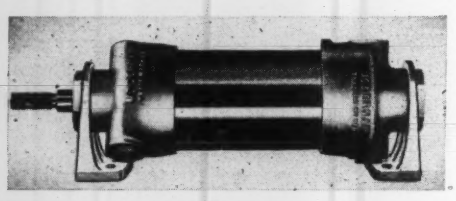
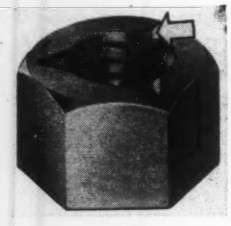
allows speed of stroke to be varied to suit the application. Advantage of the line is the variety of interchangeable mounting cylinders available; caps are designed to take one or a combination of brackets—end plates, foot brackets, swivel mountings, etc.—suited to multiple installations. All units are equipped with stainless-steel piston rods and cylinder caps are heat-treated aluminum alloy sand castings. Corrosion resistant, the cylinders are suitable for use with air,



water or oil. They are made in 2, 3, 4 and 6-inch diameter and are provided with O-ring packings to prevent metal to metal contact at wear points. Manufacturer: Modernair Corp., Oakland, Calif.

For additional information circle MD 33 on Page 257

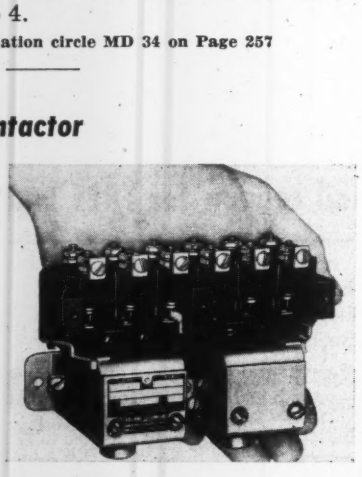
Spring Lock Nut



Self-locking Gripco nut has been improved by widening and deepening the locking indentations provided at the top of the nut. Three advantages result: Increased pressure area on threads provides sustained holding power, nut may be removed and reused many more times and still retain high locking force and the unit locks effectively on threads not held to close tolerance. All metal, the nut is unaffected by oil or chemicals and requires no lock washers or cotter pins. Manufacturer: Grip Nut Co., 310-W South Michigan Ave., Chicago 4.

For additional information circle MD 34 on Page 257

AC DC Reversing Contactor

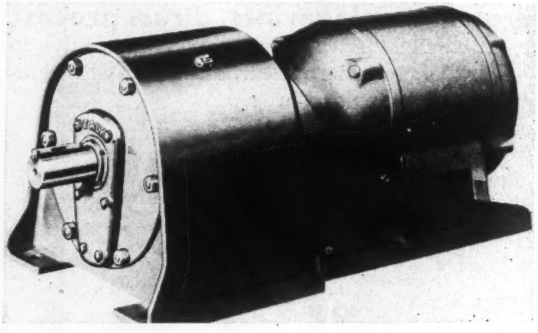


Reversing contactor for ac or dc intermittent-duty applications is of small size and may be direct-mounted on grounded panel. This control unit consists of double magnet frames and contact blocks with two three-pole mechanically interlocked armature assemblies. Double-break silver contacts have low contact resistance and are said to never require cleaning or dressing. They can be removed easily. Normally-open electrical interlocks can be provided for three-wire control by means of an interlock bar which is mounted by means of three screws. Manufacturer: Square D Co., industrial controller division, 4041 N. Richards St., Milwaukee 12.

For additional information circle MD 35 on Page 257

Gear Motors

Horizontal and vertical gearmotors in both integral and All-Motor types are available in the new Falk line. Units have all-steel housings which are light in weight and smooth in contours, and are provided with dirt and moisture-proof seal. Tradenamed Mo-



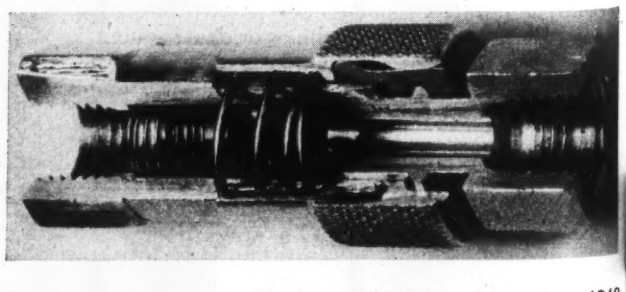
toreducers, the gearmotors are made in speed ranges down to 1 rpm. and are leak and splashproof. Manufacturer: The Falk Corp., 3001 W. Canal St., Milwaukee 8.

For additional information circle MD 36 on Page 257

Self-Sealing Tube Coupling

Self-sealing tube coupling provides automatic shut-off of fluid at one side or both sides when disconnected. Making and breaking the connection is a one-hand operation and automatic uncoupling can be provided for applications where disconnection may be desired whenever strain is placed on the fitting. Unit, known as Series P-1800, is made of high-strength aluminum-alloy bar stock with stainless steel springs, and Hycar sealing gaskets. It is corrosion resistant and leakproof under vibration. Couplings are available with $\frac{3}{8}$ and $\frac{1}{2}$-inch taper pipe threads, with sockets and plugs and with $\frac{3}{8}$ and $\frac{1}{2}$-inch hose-shank sockets. Manufacturer: E. B. Wiggins Oil Tool Co. Inc., 3424 E. Olympic Blvd., Los Angeles 23.

For additional information circle MD 37 on Page 257



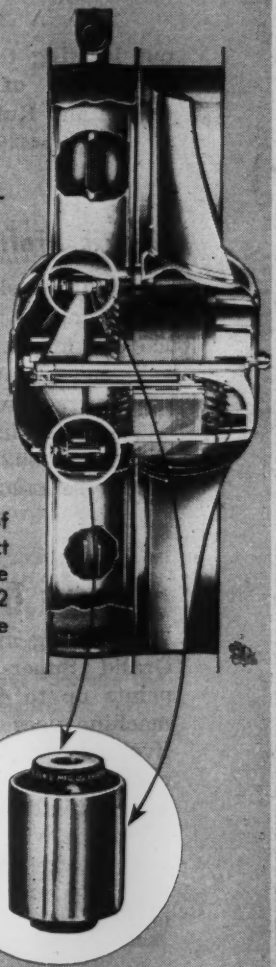
big *but quiet...*

with a LORD vibration control system

Moore Fans and Blowers move lots of air—up to 125,000 cu. ft. per minute—in a variety of industrial cooling and ventilating applications. Smooth, quiet operation is desirable in all of these applications—to avoid distracting workers, and to help assure years of trouble-free service.

The Moore Company, 544 Westport Ave., Kansas City, Mo., solved the problem of vibration and vibratory noise by mounting the motor on three Lord Tube Form Mountings. The bonded rubber mountings minimize noise transfer which would detract from employee morale and efficiency . . . prevent motor vibration from being transferred to the housing . . . assure smooth performance and long life.

Does your product have moving parts . . . or is it exposed to external vibrating forces? If the answer is yes—whether you make delicate recording instruments or massive machinery—a Lord Vibration Control System will increase your product's efficiency, durability, and customer appeal. Consult a Lord engineer. There is no obligation.



Cutaway view of the Moore Direct Drive Pressure Blower, showing 2 of the 3 Lord Tube Form Mountings.

Write for Bulletin 900 today. It describes the complete line of Lord products and services.

LORD Vibration Control Systems

LORD MANUFACTURING COMPANY • ERIE, PA.

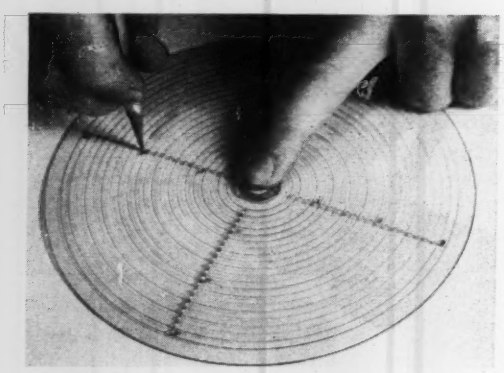
Canadian Representative: Railway & Power Engineering Corp. Ltd.

engineering dept equipment

In order to obtain additional information on this new equipment see Page 257

Self-Centering Compass

Suitable for drawing circles from ⅝ to 2 inches in radius, the self-centering compass is used by placing it on the drawing at the desired spot and using location holes to trace the arc. Advantages of the instrument include its utility in drawing tangents without locating the center, nonperforation of the paper and speed of operation. Manufacturer: Modern Gauge and Rule Co., Box 347, Los Angeles 53.



For additional information circle MD 38 on Page 257

Electric Drafting Template

Useful in electrical drafting, the No. 31 Electroneer template has cut outs for all of the commonly used symbols. The instrument is made of clear, cellulose nitrate sheet 0.040-inch thick. Printing is on reverse side to prevent wear. Dimensions are 4¼ by 4¼ inches. Manufacturer: Rapidesign Inc., P. O. Box 592, Glendale, Calif.

For additional information circle MD 39 on Page 257

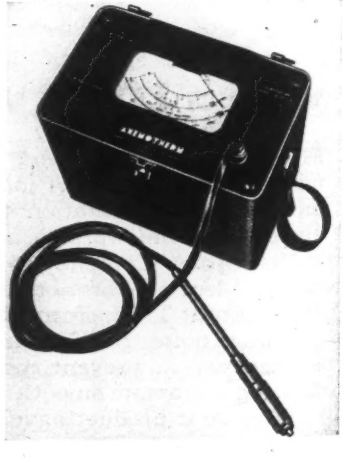
Automatic Tracing Reproducer

Operating at speeds up to 25 feet per minute, the Ozalid Super-B reproducer exposes and develops prints up to 42 inches wide in one operation. The machine uses paper in either roll or cut form, delivering the print at either the front or the back of the machine. When front delivered, the prints are automatically stacked in a tray accommodating sheets 12 inches wide and 42 inches long; spill-over tray receives larger size sheets. Features of the unit include thermostatic control of heaters, automatic humidity control and automatic ammonia feed from shipping bottle to storage tank. Unit measures 84½ inches wide, 38 inches deep and 79 inches high; it operates on 215-volt, single-phase current. Manufacturer: Ozalid Div. of General Aniline & Film Corp., Johnson City, N. Y.

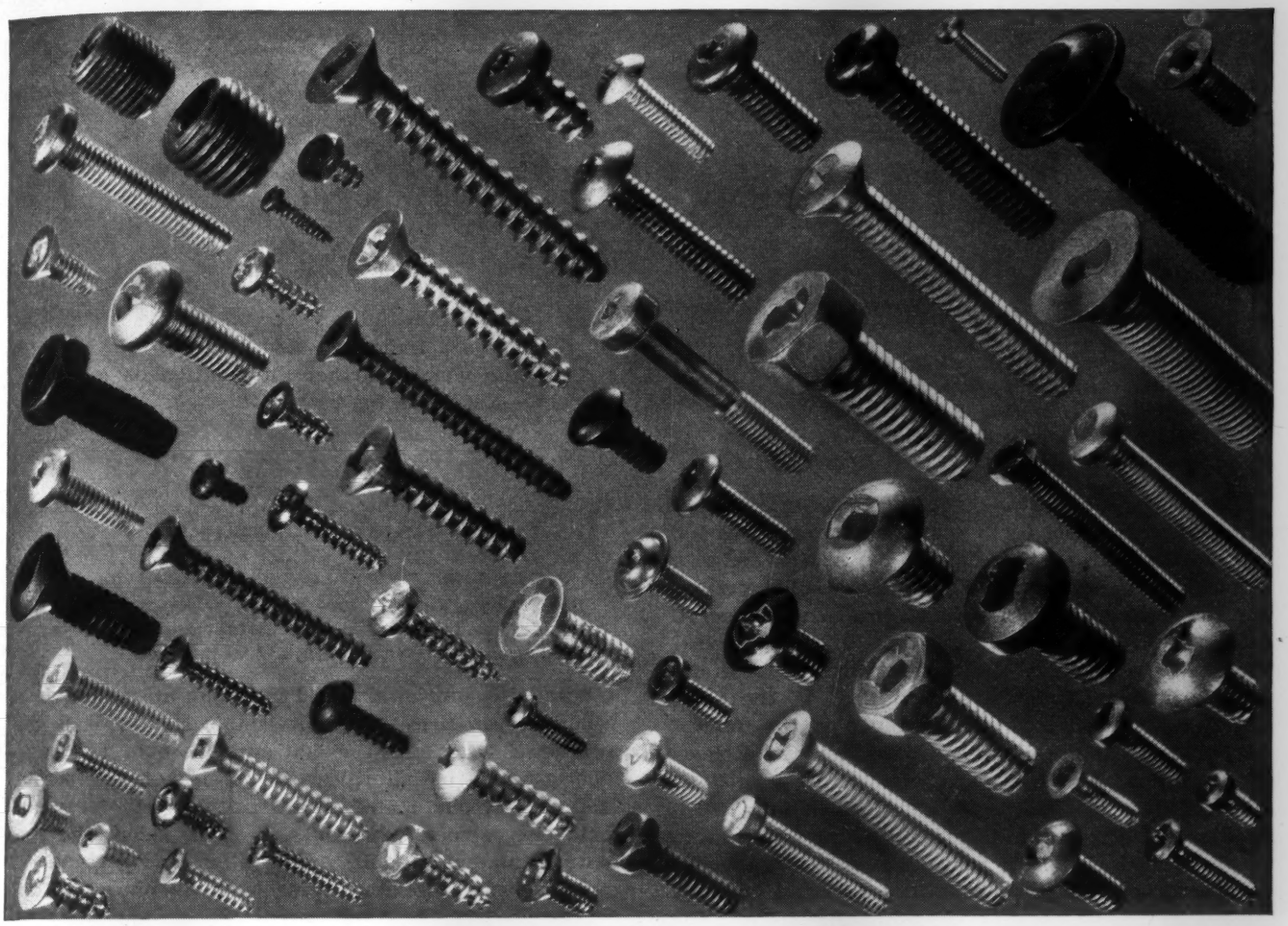
For additional information circle MD 40 on Page 257

Air-Measuring Instrument

Three-way air meter known as the Anemotherm will give air velocity, air temperature and static pressure readings. Operating on self-contained batteries the unit weighs 11 lb. It uses a small probe attached to a flexible cable, can thus take readings in relatively inaccessible places. Velocity range of the instrument is 10 to 5000 fpm; temperature range is 30 to 155 F and static pressure may be read in inches of water from 0.05 to 10 positive and 0.05 to 4 negative. Manufacturer: Anemostat Corp. of America, 10 E. 39th St., New York 16.



For additional information circle MD 41 on Page 257



CLUTCH HEAD *Is Obtainable In All Sizes and Types of Screws...* STANDARD OR SPECIAL

Regardless of the sizes or types of screws you are using now... *or plan to use*... it will pay you to weigh the profit and safety advantages of replacing them with CLUTCH HEADS.

These advantages are definite. They are vouched for by CLUTCH HEAD users operating assembly lines in virtually every branch of industry, light and heavy . . . from the world's largest automotive and refrigeration plants to delicate radio and electrical assemblies.

These users credit change-over to CLUTCH HEAD with:

1. **Production increases** ranging from 15% to 50%.
2. **Freedom from burred or chewed-up heads** due to high visibility of the recess, dead-center bit entry, and automatic straight driving.
3. **Elimination of the skid hazard** (with its consequent danger of injury to manpower and damage to fine surfaces) resulting from CLUTCH HEAD'S exclusive feature of all-square non-tapered driving engagement.
4. **Checking out a fatigue factor** because this all-square contact eliminates the need for tiring end pressure to combat "ride-out" as set up by tapered driving.

These exclusive features have established CLUTCH HEAD *as America's Most Modern Screw and their value will be immediately apparent on examination.*

CLUTCH HEAD · SCREWS ·

5. **The hurdling of "fumble spots"** . . . thanks to the Lock-On which unites screw and bit as a unit for one-handed reaching and an easy drive-home from any angle.
6. **Fractional tool maintenance cost** . . . resulting from the rugged structure of the Type "A" Bit which drives up to 214,000 screws non-stop, and which may be reconditioned on-the-spot in 60 seconds.
7. **The curing of field service "headaches"** because the CLUTCH HEAD recess is basically designed for operation with a common screwdriver.

For preliminary investigation, we suggest you send for screw assortment, sample of the Type "A" Bit, and illustrated Brochure.

UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7

Assets to a Bookcase

Servomechanism Fundamentals

By H. Lauer, R. Lesnick and L. E. Matson, RCA Victor Div., Radio Corp. of America; published by McGraw-Hill Book Co., New York; 277 pages, 6 by 9 inches, clothbound; available through MACHINE DESIGN, *$3.50 postpaid.*

This book discusses the operating features of servomechanisms and sets forth systematic procedures for their design with emphasis on the transient analysis of elementary servomechanisms. A detailed derivation has been made of the basic properties of servo control devices and their relation to the physical principles that govern their operation. Conventional mathematical methods have been used in the solution of differential equations involved in the numerous practical examples given. To further assist those who have not had recent experience with the calculus involved, the problems are solved in detail. Such aspects as viscous-output damping, error-rate damping, combined damping, and stabilization networks are discussed and the elementary forms of control systems and basic components are covered carefully.

□ □ □

Design of Machine Elements

By M. F. Spotts, associate professor of machine design, The Technological Institute, Northwestern University; published by Prentice-Hall Inc., New York; 402 pages, 6 by 9 inches, clothbound; available through MACHINE DESIGN, *$6.65 postpaid.*

This new text, written by a man who has an enviable record of teaching the subject, contains much material that makes it of special interest at this time. Principal attention has been directed to the application of the elements of engineering mechanics to the analysis of representative machine components, little attention being given to the actual forms of the items as they appear commercially. This has been done, as the author explains in the preface, because such information is readily available from catalogs. The excellent illustrations contain much more detail than is usually given in works of this type.

Whereas the usual machine elements; shafts, springs, screws, belts, bearings, and gears, are all adequately discussed, the treatment of gears constitutes an innovation in the field. The traditional material on the strength of conventional gearing has been cut to the bone and space given to the principles underlying extended center distance and long and short addendum gearing. Particularly to be noted are the excellent bibliographies which accompany each chapter. These are up-to-date, stick close to the subject indicated, and are of value to the reader who wishes further information on a specific subject.—*Reviewed by C. E. Balleisen.*

□ □ □

Metals Handbook—1948

Edited by Taylor Lyman; published by the American Society for Metals, Cleveland; 1444 *pages,* 8 *by* 10¾ *inches, clothbound; available through* MACHINE DESIGN, *$15.00 postpaid.*

Far exceeding in size and coverage all its previous volumes, the 1948 edition of Metals Handbook is the combined work of over 600 specialists in the engineering and metallurgical fields. Covering ferrous and nonferrous metals and such aspects as wear, oxidation, stress corrosion and stress relief, the volume is an outstanding presentation and virtually a required reference for engineers in all phases of design and development. The book is divided into four principle sections: General discussion of processes and methods, ferrous metals, nonferrous metals and constitution of alloys. First section contains 74 articles covering all aspects of manufacture and service, while the sections on ferrous and nonferrous metal contain 176 articles and 220 data sheets describing in detail the properties of the materials. The constitution of alloys section is said to contain the first extensive collection of alloy phase diagrams ever published in this country.

Complete revised price list of national standards approved by the American Standards Association is now available. The 24-page booklet lists the standards in numerical order, giving a description and price of each. Complete index greatly facilitates use of the list. It is available from the American Standards Association, 70 E. 45th St., New York 17.

Entitled "Stress Corrosion Cracking of Mild Steel," a recently available booklet by J. T. Waber and H. J. McDonald of the Illinois Institute of Technology is largely a reprint of a series of articles which appeared in Corrosion and Material Protection Magazine. It presents a general theory of stress corrosion and the importance of nitrogen in this phenomenon and is replete with charts and bibliographies. This 100-page, 5¾ by 8¾-inch paperbound booklet is published by the Corrosion Publishing Co., 1131 Wolfendale St., Pittsburgh 12 and is available from them at $2.00.

CALL ON CROLOY

STAINLESS STEEL
Seamless and Welded
TUBES with Molybdenum for superior corrosion-resistance and strength

When you need tubes with high resistance to severely corrosive solutions for pressure or mechanical applications, call on these B&W Croloys . . . They were developed by B&W expressly to help solve this problem . . . so they meet the requirement as only tailor-made tubes can.

Because of their molybdenum content, all of these Croloys are superior to many of the plain stainless grades, not only in combating corrosion, but also in their resistance to creep and oxidations at elevated temperatures. Their time-saving, cost-cutting advantages have been convincingly demonstrated in a wide variety of severe service conditions.

B&W can supply these Croloy analyses in both seamless and welded tubes. Perhaps they will solve tough tubing problems in your plant or in equipment you make, as they have in others. So ask today for full information.

TA-14535

B&W

Seamless and Welded Tubular Products in a full range of Carbon, Alloy, and Stainless Steels for All Pressure and Mechanical Applications.

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Stationary and Marine Boilers . . . Boiler Components . . . Pulverizers . . . Fuel Burning Equipment . . . Refractories . . . Chemical Recovery Units . . . Process Equipment . . . Alloy Castings.

BABCOCK & WILCOX
SEAMLESS & WELDED TUBES
THE BABCOCK & WILCOX TUBE COMPANY
GENERAL OFFICES: BEAVER FALLS, PA.
PLANTS: BEAVER FALLS, PA. AND ALLIANCE, OHIO.

Noteworthy Patents

VIBRATION ABSORPTION as well as ability to operate under angular and parallel misalignments are requirements said to be met by a new flexible coupling arrangement invented by Stuart D. Pool. Assigned to International Harvester Co. under patent 2,437,891, the unique coupling utilizes as the flexible driving member a standard double-angle V-belt. Woven over projections on the hub member and under projections on the outer member to form a sinuous connection, the belt is clamped under slight pressure to prevent any looseness.

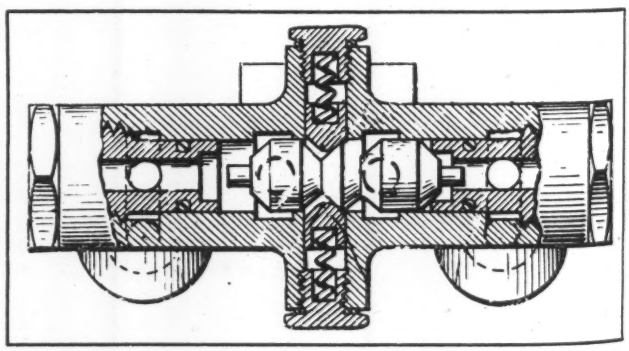
FLUID ACTUATION is achieved without the use of the conventional hydraulic piston on a clamping or gripping device covered in patent 2,437,131. Particularly suited to such mechanisms where the required stroke is short, the means outlined in this patent, assigned to H-P-M Development Corp. by Victor S. Shaw, consists of a confined, fluid-filled flexible tube. By confining the flexible tube in a hollow chamber, plunger-like machine members can be actuated hydraulically over limited strokes either by end or side expansion of the tube member.

AUTOMATIC CENTERING of irregular cylindrical objects such as electrodes, logs, etc., is obtained by means of a novel hydraulic device covered in Patent 2,441,925. Regardless of the diameter, the center of the piece is moved to the machine centerline. Movements of the V type gripping jaws of the device are interconnected with a hydraulic reversing valve so as to synchronize the rate at which the two advance toward each other to center the piece. Cables operating over a series of sheaves continually correct the setting of the valve plunger to bring both jaw actuating pistons together simultaneously. Patent is assigned to the Oilgear Co. by Ervin C. Wege.

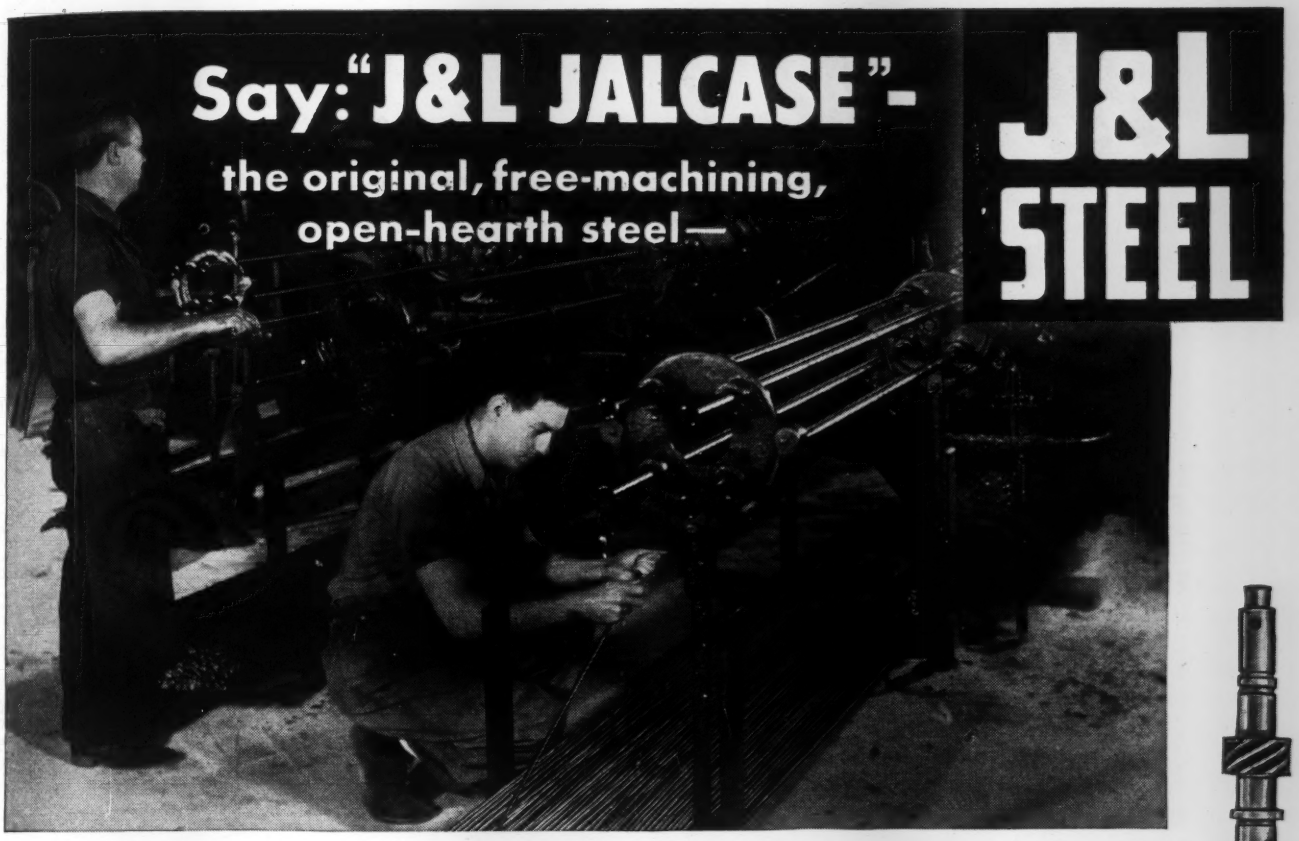
ATMOSPHERIC PRESSURE is maintained within a sealed machine housing while loss of oil at the same time is prevented by means of an arrangement covered in patent 2,442,489. Assigned to Bendix Aviation Corp. by Jakob B. Frei, the venting method is based on use of a hollow or drilled shaft. Interior of the housing is directly vented to the atmosphere by the drilled hole which can be connected to any or various portions of the interior by means of radially drilled ports. Although such ports may at times be immersed in lubricant, so long as the static oil level is not above the centerline of the shaft leakage does not occur. In operation, centrifugal force makes it impossible for lubricant to escape and build-up of gaseous pressures in excess of atmospheric is prevented.

POSITIVE, ACCURATE ACTION in opening and closing, especially necessary in applications such as metering, is achieved with a new valve which operates without sliding between the valve parts. A double acting face cam arrangement opens and closes the valve poppet, holding it in either position, positively. The poppet assembly is guided by rollers to reduce friction and the poppet is held by spring arms to provide resilient action in seating. The patent is assigned to Rohlm Mfg. Co. by Emmett F. Sarver.

OPERATING AUTOMATICALLY in response to pressure from either of two hydraulic pressure generators, a shuttle valve invented by O. A. Kehle feeds pressure into a single system. Pressure from an auxiliary pump, on breakdown of the main unit, causes the shuttle to shift instantly, closing off the



alternate feed line. Normal wear on the valve seat encountered in service is offset by means of adequate takeup action in the valve detents. The spring detent action is so arranged that under all operating conditions, including during shifting of the shuttle, only one inlet is open at a time. Interflow between inlets is prevented.

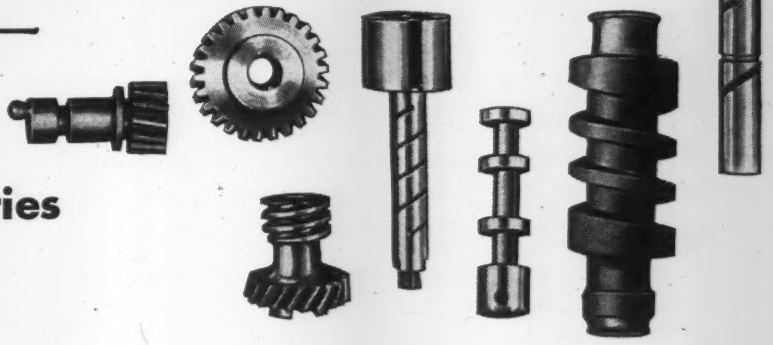


if you want the best in—

✓ machinability

✓ heat-treating properties

✓ physical properties



There's more to J&L Jalcase Steel than a grade number. That's why, if you want the best, you must specify "J&L JALCASE."

- It is the *original*, free-machining, open-hearth steel.
- It still is the outstanding steel in its class today.
- Its machining properties closely approach those of Bessemer steel.
- It machines with a fine finish.
- It is easy to heat treat by conventional and high-speed induction methods.
- It lengthens tool life.
- It reduces production costs.

Jalcase is available in a range of grades to suit a wide variety of applications. It is supplied as cold-drawn or cold-drawn-with-metallurgical-processing, which includes special tempering treatments. Thus many parts made of this material may need no further heat treatment after machining.

Typical Jalcase analyses are found in the A.I.S.I. 1100 series wherein the manganese content is 1.00% to 1.65%, such as in Grades C-1117 through C-1144.

Let us send you complete information on J&L Jalcase—the *modern* free-cutting steel. Write to: Jones & Laughlin Steel Corporation, 410 Jones & Laughlin Building, Pittsburgh 30, Pa.

JONES & LAUGHLIN STEEL CORPORATION

AMERICA'S FOREMOST PRODUCER OF FREE-CUTTING, QUALITY-CONTROLLED STEELS

MEN...of...machines

A. C. MONTEITH, a member of the Westinghouse Electric Corp. engineering staff for twenty-five years, has recently been elected vice president in charge of engineering and research. After graduating from Queens University, Kingston, Ont., Canada, Mr. Monteith joined the corporation in 1923 as a student engineer and was assigned to the central station engineering department the following year. He became manager of the department in 1938 and three years later was named to a similar position in the industry engineering department. Since 1945 when he took over the dual position of manager of headquarters engineering and director of education, Mr. Monteith has promoted all forms of engineering activity relating to the development of young graduate engineers. One of the outstanding engineering accomplishments with which he has been associated during the past three years is the electric analog computer now being completed. The computer handles engineering calculations and solves problems in the fields of electrical circuits, machinery, applied mechanics, hydraulics and heat flow. Mr. Monteith is a member of the American Society of Mechanical Engineers, the American Institute of Electrical Engineers and the National Electrical Manufacturers Association and has contributed numerous papers and articles on engineering subjects. He is also the recipient of the Order of Merit, highest award of the Westinghouse corporation for service and accomplishment.

A. C. Monteith

EDWARD C. WELLS, formerly vice president and chief engineer, Boeing Airplane Co., has been elected vice president—engineering. During his career with Boeing, with whom he has been associated since 1930, Mr. Wells has done preliminary design work on high-performance pursuit planes for the Army and has served as assistant project engineer on the Boeing model 299 (prototype of the B-17 Flying Fortress), chief preliminary design engineer, chief project engineer, and assistant chief engineer. In 1943 he became chief engineer at the age of 33, and in May, 1947 was elected a vice president of the company. In addition to the Lawrence Sperry award which he received in 1942 for his work in the design of four-engine aircraft, Mr. Wells was presented the Fawcett aviation award for "the greatest single contribution for the scientific advancement of aviation during 1944."

Edward C. Wells

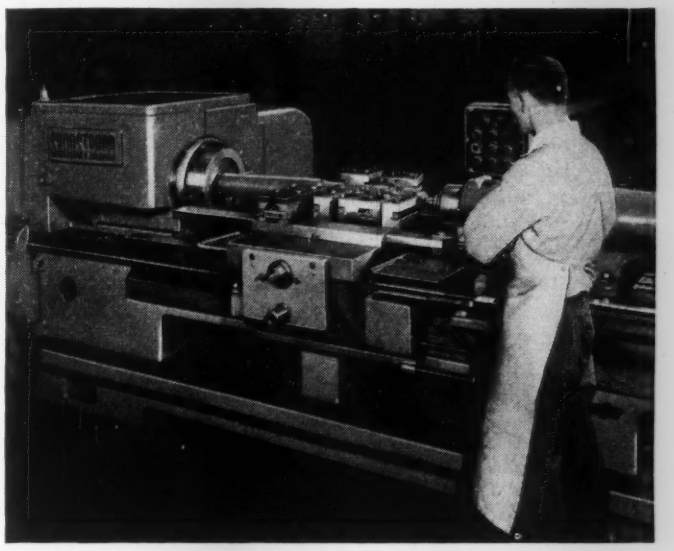
Lysle Wood

LYSLE WOOD, promoted from assistant chief engineer to chief engineer of the Boeing Airplane Co., has been associated with the company since 1926. He has been responsible for the organizational duties of the engineering division since 1943 when he was named assistant chief engineer. His previous experience with the company includes service as project engineer of the Boeing Stratoliner, pioneer of altitude-conditioned commercial

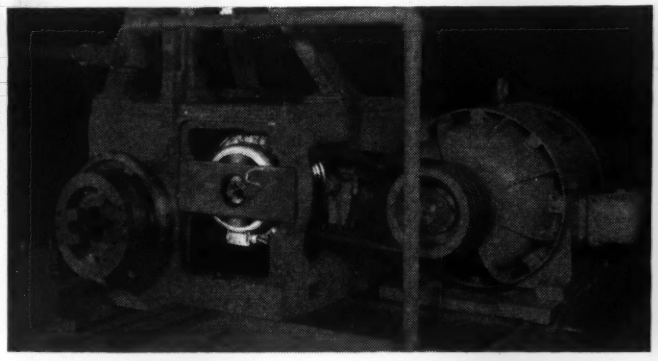
HOW TO BETTER CONTROL AN AUTOMATIC LATHE

...give it a Brake*!

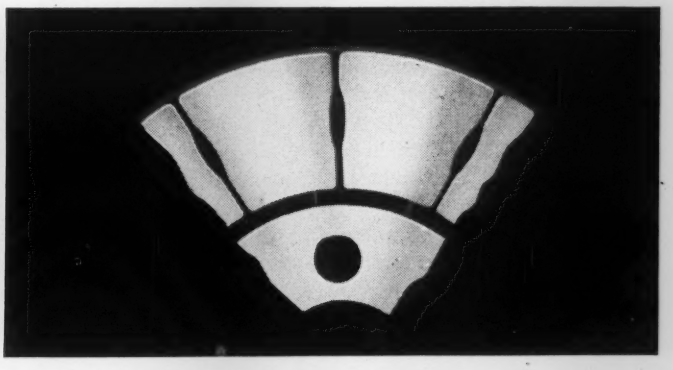
***And the Brake to give it is a WARNER ELECTRIC INDUSTRIAL CLUTCH-BRAKE**



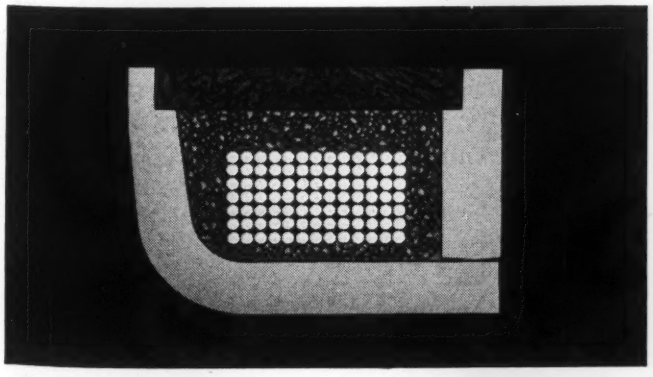
SUNDSTRAND MACHINE TOOL CO. USES 3 Warner Electric Industrial "ICB" units on their Model 16 Automatic — Two on main spindle drive and one on rapid traverse. Here's what they say about them — "Easy to Control." Main drive motor is standard 75 hp. and constantly running. Warner ICB* units give positive instant control for starting and stopping of spindle. That means short cycle time . . . no special electrical equipment . . . no sudden power surges on factory lines.



HERE'S WARNER ICB UNITS installed on drive shaft of Sundstrand Model 16 Automatic. Sundstrand says these units are "compact, easy to install" . . . and most important "need no adjustment." ICB Units are available in wide range of sizes to meet requirements. Can also be fitted to standard NEMA motor shafts.



ARMATURE SECTION: One of only two parts for either Clutch or Brake units. Consists of magnetic segments welded to steel backplate (see cut). Especially designed for high heat dissipation. Heat has no effect on unit efficiency because segment expansion is always linear . . . thus keeping full magnet contact at all times.



MAGNET SECTION: The other of the two parts for either Clutch or Brake units. Consists of electro-magnet faced with long-wearing, high friction material. Power, applied through coils imbedded below (see cut), uses both friction *plus* magnetic attraction for fast, super-powerful clutch or brake action.

• Warner ICB Units* are low-cost key to more automatic, safer operation of wide variety of motors and machinery . . . give you infinite control of degree of clutch or brake action. For details or engineering assistance write: INDUSTRIAL DIVISION, WARNER ELECTRIC BRAKE MFG. CO., Beloit, Wis.

WARNER
ICB UNIT*

*ICB Unit — The trade designation for the Warner Electric INDUSTRIAL CLUTCH OR BRAKE UNIT.

transports. He also served as commercial projects engineer, becoming executive engineer in 1942.

♦

N. D. SHOWALTER has been appointed assistant chief engineer, Boeing Airplane Co., succeeding LYSLE WOOD. He served as test pilot as well as project engineer on many of Boeing's airplanes during his twenty years with the company. Recently he has been engaged in supervising extensive tests of commercial transports, bombers and jet bombers. In addition to his new duties, he will continue in charge of these programs.

♦

WILLIAM M. WALWORTH has returned to Reo Motors Inc., Lansing, Mich., as chief engineer succeeding KARL K. PROBST who has resigned to enter the consulting and development field. Mr. Walworth began his career in the automotive industry joining the Reo organization immediately after graduation from Massachusetts Institute of Technology. After twelve years in its engineering department he became asssociated with Mack Mfg. Corp. and was elected vice president and chief engineer of that company in 1946.

♦

ARTHUR N. BECVAR, who has been associated with the appearance design division of General Electric Co. at Bridgeport, Conn., since 1945, recently was named assistant director. Previous to this appointment he served as co-ordinator of design for the traffic appliance section of the division.

♦

M. P. WINTHER has been appointed vice president and director of engineering, Eaton Mfg. Co., Cleveland. Mr. Winther joined the company in 1946 when Eaton acquired Dynamatic Corp., Kenosha, Wis., of which he was president and general manager. In addition to his new duties, Mr. Winther will continue as president of Dynamatic which is operated as a subsidiary of the Eaton company.

♦

HAROLD O. KRON, recently appointed chief engineer of Philadelphia Gear Works Inc., Philadelphia, for the past seven years had been analytical engineer with the Baldwin Locomotive Works. A mechanical engineering graduate of Drexel Institute of Technology and a registered professional engineer in Pennsylvania, Mr. Kron was a designer and engineer with the American Engineering Co. from 1935 to 1940.

♦

CARL F. SCHULTZ, a member of the Ford Motor Co. engineering division since October, 1946, has been appointed engineering assistant to the general manager of the Lincoln-Mercury Div. WILLIAM BURNETT, chief experimental engineer has been appointed assistant chief engineer for Ford passenger cars.

♦

G. LESTER JONES, long identified with the design and manufacture of precision instruments and equipment, has been appointed chief engineer of Lear Inc., Grand Rapids, Mich. Mr. Jones early in his career served as assistant to Dr. Sperry at Sperry Development Co., Brooklyn, N. Y., and for twelve years was chief engineer of Sperry Products Co. As engineering and production manager of Sperry Gyroscope Co., Great Neck, N. Y. for four years, he was responsible for the design and manufacture of air flight instruments and automatic pilots. During the war Mr. Jones was associated with the War Products Div., Eversharp Inc., and for the past year he has been assistant to the president of the Indian Motocycle Co.

♦

JOHN S. NEWTON has been appointed manager of engineering of the Eddystone Div., Baldwin Locomotive Works. Mr. Newton formerly was associated with the Westinghouse Electric Corp., for the past nine years serving as assistant engineering manager of the steam division at South Philadelphia. In that capacity he was in charge of many important phases of design and application of steam and gas turbines, particularly in the marine and transportation fields. Associated with Westinghouse since graduation from Oregon State College in 1930, Mr. Newton spent his first nine years with the company at East Pittsburgh engaged in the design and application of large d-c machinery.

♦

LOREN J. O'BRIEN has been appointed chief engineer of the axle division of Spicer Mfg. Div., Dana Corp., Toledo.

♦

DWIGHT R. ABRAMS has joined Henry & Hutchinson, design engineers of Decatur, Ga. Mr. Abrams formerly was chief of the modification section of the Bell Aircraft Company's bomber plant at Marietta, Ga.

♦

DR. WILLIS R. WHITNEY, who founded the General Electric Research Laboratory, Schenectady, N. Y., in 1900, was honored recently on the occasion of his eightieth birthday. A painting of Dr. Whitney was unveiled which will hang in the foyer of the new research building now being constructed at the Knolls, near Schenectady. Dr. Whitney retired as vice president in charge of research for General Electric in 1940.

♦

DALLAS S. CASLEY has been appointed chief engineer of the Parkersburg, W. Va. plant of the Penn Metal Co. Mr. Casley will assist in the extensive construction program and improvements to machinery and equipment to extend over the next few years.

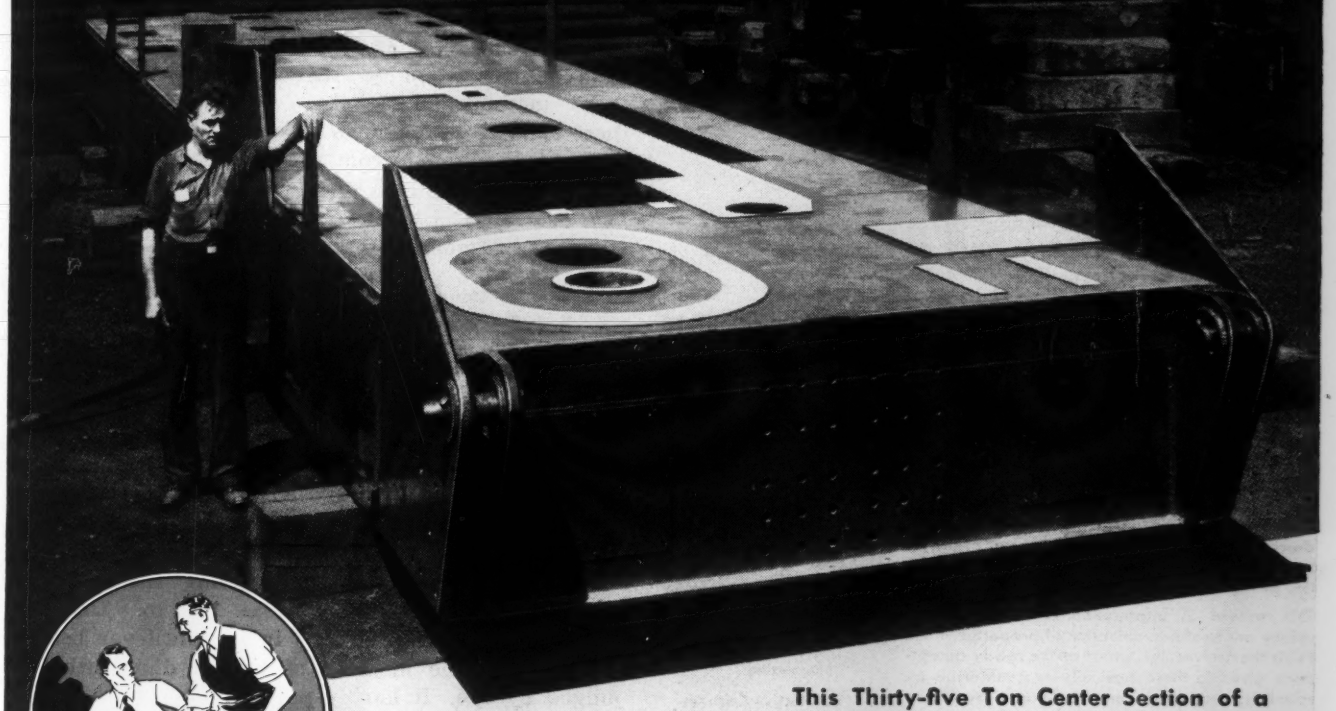
♦

M. E. BROOKS, formerly chief engineer of the Massena works of the Aluminum Co. of America, Massena, N. Y., has been transferred to the Pittsburgh office of the company as assistant chief mechanical engineer.

♦

GERALD VON STROH, assistant manager of the development engineering division of Lukens Steel Co., Coatesville, Pa., has been appointed director of the bituminous coal industry's program to develop a continuous mining machine. Mr. Von Stroh has served in engineering capacities in the past for Kaiser Services, Hughes Aircraft Co., and Consolidated Aircraft Corp.

Steel-Weld FABRICATION



This Thirty-five Ton Center Section of a base for a large earth moving machine is another example of Mahon workmanship in Steel-Weld Fabrication. If you are searching for a reliable source for welded steel in any form—a source with complete, modern facilities for rough or finished machine work—the reputation of Mahon design engineering experts and Mahon master craftsmen, who have achieved a degree of excellence rarely equaled in this highly specialized art, are ample assurance that you will receive a better, smoother appearing job, embodying every advantage of Steel-Weld Fabrication.

THE R. C. MAHON COMPANY
Detroit 11, Michigan

Engineers and Fabricators of Welded Steel Machine Bases and Frames, and Many Other Welded Steel Products

MAHON

Silicone News

DC SILICONES

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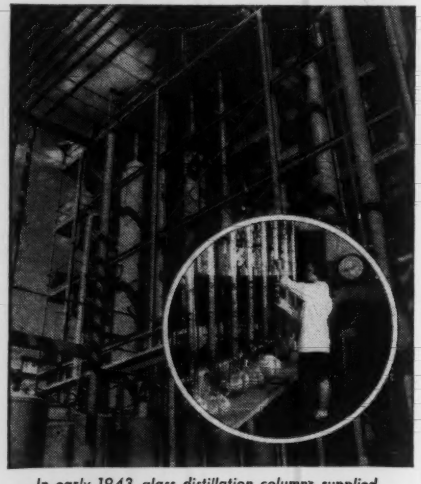

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Curved Beams

(*Continued from Page* 126)

to the load, *Fig.* 13, it may be said that in general they likewise are of an inconsequential order. It should be remembered that all the calculations covered in this article are for deflections in line with the applied force, i. e., the component of the deformation parallel to the line of action of the applied force. The deflection perpendicular to this is a definite amount and could be calculated without difficulty but in practically all cases is not warranted.

ILLUSTRATIVE EXAMPLES: To make the foregoing procedures clear a typical curved beam deflection problem will be solved by each of the three methods given in this article. It will be noted that the three solutions are close together in values, indicating that lack of exactness in calculating moments of inertia, variations in castings, etc., are more likely to cause discrepancies than is the approximate nature of these methods. Dimensions of the beam used in these examples are shown in *Fig.* 14.

Chart Solution. From the dimensions on *Fig.* 14, $I_o/I_p = 3.5/0.91 = 3.85$ and $L/R = 8/4 = 2$. From *Fig.* 8, $a/R = 3.13$ and from *Fig.* 9, $K = 17.2$. Substituting in Equation 5

$$\delta = K\frac{PR^3}{EI_o} = 17.2\frac{1000 \times 64}{12 \times 10^6 \times 3.5} = 0.026\text{-in.}$$

Equivalent Beam Solution. This solution will employ the curve of *Fig.* 11 to determine the length of the equivalent cantilever beam. This is done in the solution below for illustrative purposes. Equation 7 could also be used with about the same degree of overall accuracy.

From *Fig.* 11 the L/R ratio of 2 gives the value 3.45 for the l/R ratio, thus giving the equivalent length of beam as $3.45 \times 4 = 13.8$ in. Using the equivalent length $l = 13.8$ in. a cantilever beam is set up with the moment of inertia distribution adjudged by eye. It hardly pays to attempt to get this to a high degree of accuracy. The basic idea is to spread the curved beam length over the new and longer equivalent beam.

By means of graphical methods as in *Fig.* 15 the deflection may be found. The M/I diagram is constructed first. In *Fig.* 15 this has been laid off to a vertical scale of 2000 M/I units per inch and to a horizontal scale of 2.63 in. per in. This scale allows the beam length to be drawn in fourteen three-eighth-inch divisions.

Graphical integration of the M/I curve is performed in the usual manner by first laying off distances *ab, bc,* etc., on a vertical line (shown at lower right of *Fig.* 15), proportional to the ordinates labeled to correspond on the M/I diagram. The ray polygon is completed by selecting a pole distance p and drawing rays from the pole O to the points, *a, b, c,* etc. For this example the ratio of curve ordinate to ray polygon is $k = 4$ and the pole distance is $p = 4$ inches.

For each division, z, along the beam length a

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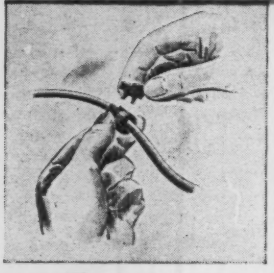

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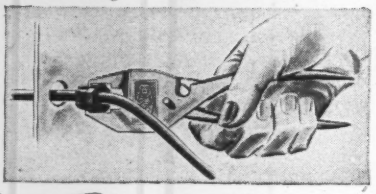

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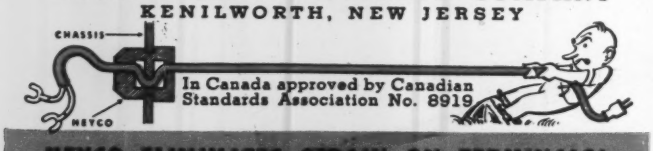

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TABLE I
Curve Area Solution for Deflection

Station	s	a	a^2	I_x	$\frac{a^2}{I_x}$	Mean Ordinate	ΔS	$\Delta S \times M.O$
0	0.0	0.0	0.0	0.90	0.0			
						0.432	1.0	0.43
1	1.0	1.0	1.0	1.15	0.868			
						1.864	1.0	1.86
2	2.0	2.0	4.0	1.40	2.86			
						4.25	1.0	4.25
3	3.0	3.0	9.0	1.60	5.63			
						8.43	1.0	8.43
4	4.0	4.0	16.0	1.80	11.23			
						11.88	1.0	11.88
5	5.0	5.0	25.0	2.00	12.50			
						14.43	1.0	14.43
6	6.0	6.0	36.0	2.20	16.35			
						18.38	1.0	18.38
7	7.0	7.0	49.0	2.40	20.40			
						22.50	1.0	22.50
8	8.0	8.0	64.0	2.60	24.60			
						26.85	1.047	28.15
9	9.047	9.035	81.6	2.80	29.10			
						31.50	1.047	33.00
10	10.094	10.00	100.0	2.95	33.9			
						35.90	1.047	37.60
11	11.142	10.83	117.4	3.10	37.9			
						39.20	1.047	41.00
12	12.189	11.46	131.5	3.25	40.5			
						40.90	1.047	42.80
13	13.236	11.86	140.5	3.41	41.3			
						41.30	1.047	43.30
14	14.283	12.00	144.0	3.50	41.3			
							Total	308.01

parallel to the corresponding ray is drawn; for example, between the ordinates *ab* and *bc* the line is parallel to *Ob*. The distance 3.90 in. is translated into actual deflection at the end of the beam by multiplying by the deflection scale, which is calculated as follows:

$$\text{Deflection scale} = \frac{pszk}{E} \times \frac{M}{I} \text{ scale}$$

$$= \frac{4 \times 2.63 \times 3 \times 4}{12{,}000{,}000 \times 8} \times 2000$$

$$= 0.00693 \text{ in. per in.}$$

Hence the deflection is $\delta = 0.00693 \times 3.90 = 0.027$ in.

Accuracy of this method of solution depends to a large degree on the ratio of I_o to I_p. As this ratio increases the results tend to become more inaccurate.

Curve Area Solution. In *Fig.* 16 the beam is shown divided into a series of divisions Δs, in the same manner as *Fig.* 5. TABLE I lists the dimension a and moment of inertia I at each station, as well as the value of a^2/I. A curve of a^2/I could be plotted versus s, as in *Fig.* 6, but a tabular solution may be performed without the graphical construction by following the procedure indicated in the last three columns of TABLE I. Area of the curve is proportional to the sum of the figures in the last column, that is,

$$\Sigma\ \Delta s \times M.O. = 308 = \int_o^s \frac{a^2}{I}\, ds$$

from which

$$\delta = \frac{P}{E} \int_o^s \frac{a^2}{I}\, ds = \frac{308 \times 1000}{12{,}000{,}000} = 0.0256\text{-in.}$$

Comparing the results of the three methods, 0.026, 0.027, and 0.0256-in. respectively, it is seen that the greatest difference is about 5 per cent of the deflection.

How welding simplifies the design of brackets

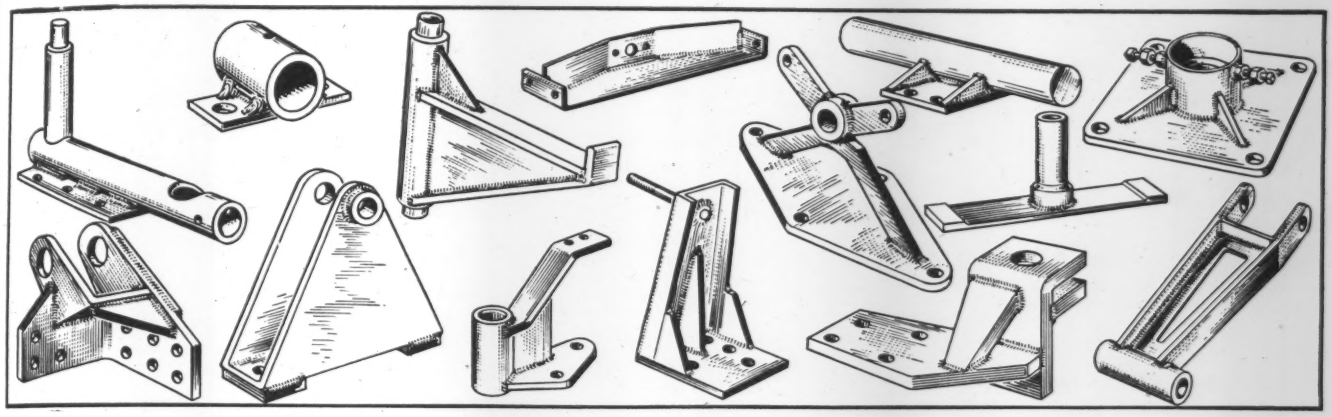

Fig. 1. Typical machinery brackets for various applications *built at lower cost with arc welding.*

WELDING builds all types of component parts, like the brackets shown in Fig. 1 . . . stronger and with less material. Here are several suggestions for building better brackets at lower cost:

Simplest in design are the brackets shown in Fig. 2, made either from separate members or from a single piece sheared and form-bent. For greater rigidity, the cantilever arm can be built from an "I" section (Fig. 3). Two or more of these "I" sections may be placed side by side and butt welded.

Heavy loads are carried with the channel construction shown in Fig. 4. For rigidity and light-weight construction, steel tubing is form-bent and welded to the supporting member (Fig. 5). With tube design, less welding is required.

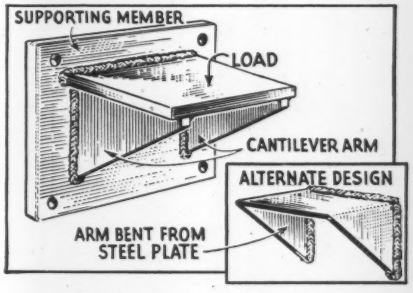

Fig. 2. *Simple bracket design* for normal loading.

Improved product appearance and high product strength are combined by using totally enclosed box-type construction (Fig. 6). Individual parts are fabricated from standard mill shapes or are cut from steel plate.

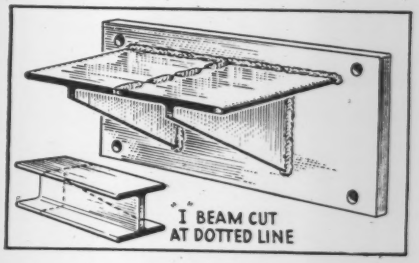

Fig. 3. *Alternate welded design* for low-cost construction. Standard "I" beams are cut and fillet welded to supporting member.

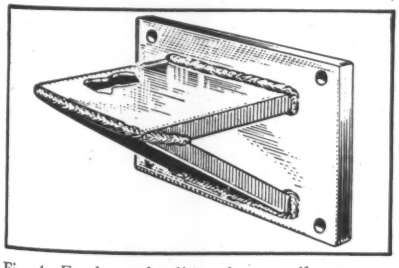

Fig. 4. *For heavy loading*, the cantilever arm is made from channels flame-cut to shape and welded.

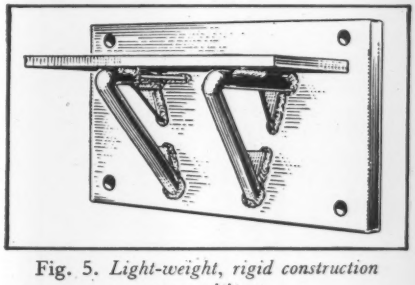

Fig. 5. *Light-weight, rigid construction* uses tubing.

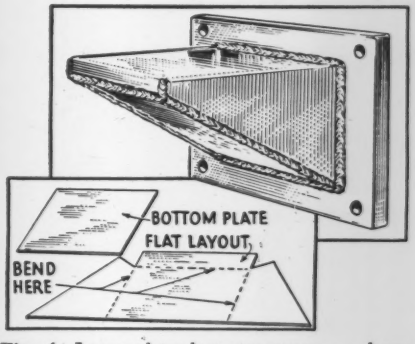

Fig. 6. *Improved product appearance . . .* box-type construction with members sheared, bent to form and welded.

More detailed data on the design of brackets for arc welding is contained in the "Procedure Handbook of Arc Welding Design and Practice." Price $1.50 postpaid in the U. S. A.; elsewhere $2.00.

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STEEL TREATMENTS

(*Continued from Page* 116)

in treating alloy steels. When the usual alloying elements are added to steels they become too sensitive for the fast water quench and are likely to crack. Consequently, the slower oil quench is commonly used. As noted before, the alloy steels are tougher and, since less strains are induced by the milder oil quench, distortion is less than on water-quenched steels. *Fig.* 13 shows a typical part (worm gear) made from an oil hardening steel (medium carbon) being quenched in oil.

Air quench: This involves cooling the part from the critical temperature in open air or with an air blast. It is used on the highly alloyed air hardening steels marketed by various tool steel companies. Very fussy jobs that have to be extremely hard and at the same time must hold their shape as perfectly as possible are treated by this method. Rolls and similar machine parts are occasionally treated in this manner. The average machine designer finds relatively little use for this treatment; most of it is used on tool and die jobs.

INTERRUPTED QUENCH: This method of hardening is generally applied to the through hardening medium and high-carbon steels although it is used occasionally in carburizing. It is best suited to relatively small parts principally to hold distortion and cracking in treating to a minimum and is well adapted to intricate sections. Most of the oil hardening type steels are adaptable to this treatment. The three types of interrupted quench treatments are as follows:

Martempering: This involves quenching (after properly heating the steel to the quenching temperature) into a suitable salt bath which is maintained at a temperature of about 300 to 500 F and holding in the salt quench until the temperature is equalized throughout the piece. The part is then taken out, cooled in air and then drawn to the desired hardness. This permits the structure to change more readily, resulting in less strains than would have been the case if it had been quenched in cool oil. About 3 inches is the maximum cross section that can be fully hardened by this method. It is effective on tool steel parts that have to hold their shape and still have the toughness generally associated with the oil hardening type analyses, alloy gears that require a high hardness with minimum distortion and greater fatigue life, and also on carburized parts where excess distortion might cause trouble.

Austempering: The mechanics of this treatment are similar to Martempering with exception that the steel is quenched in a salt bath which is about 400 to 850 F depending upon the section involved and no subsequent drawing is necessary. It is used on sections usually not over 1-inch and develops hardnesses of about 48 to 55 Rockwell C or about the same hardness as would normally be obtained by drawing to 400 to 850 F with a standard quench-and-draw treatment. Here again distortion is held to a minimum and the treatment usually results in a tougher and

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more ductile product than is obtainable by regular quenching and drawing. The process is used mainly on alloy and tool steels of 0.50 per cent carbon or over.

Isothermal: If physical properties similar to that obtainable in small sections by Austempering are desired in larger sizes (up to about 2 inches), this method can be used. It involves quenching into an agitated salt bath at 450 to 600 F, holding there long enough for the temperature of the part to become equalized and then transferring to another bath at a higher heat which serves to draw the piece, *Fig.* 14.

SUBZERO TREATMENT: This is a somewhat controversial method of heat treating and metallurgists differ in their opinions as to the effect on the piece being treated and also as to the mechanics of the method. Reduced to its simplest form it involves transferring a part that has already been treated by conventional heat treating procedure to a very cold medium, such as liquid air or dry ice which exhibits a temperature of minus 100 to minus 120 F. One widely held theory is that the extreme cold forces the internal changes due to treating to completion, thus stabilizing the metal. For this reason tool steel gages which have to maintain accurate size in service under varying conditions are parts most frequently treated in this manner. The only sure way to determine whether a job is adaptable to this cold treatment is to try it.

The application guide shown in TABLE III may serve to highlight some of the points brought out in this discussion of the selection of steels and their heat treatments. It is apparent that no hard and fast rule can be laid down stating that one group of parts should be treated in one manner and another group in another manner. As a matter of fact it is sometimes difficult to decide which is the best treatment for a part even with all the latest and best knowledge of metallurgy at one's fingertips. Frequently different steels and heat treatments have to be actually tried out before the proper combination is discovered, but basic information on steels and their treatments will materially shorten the time necessary to arrive at the proper conclusion.

BUSINESS AND SALES BRIEFS

ELECTED president of Jack & Heintz Precision Industries Inc., Kenneth G. Donald succeeds Byron C Foy who recently resigned. Mr. Donald will continue as a vice president of Robert Heller & Associates, a Cleveland management engineering firm. Concurrently, the aviation division of the company has opened a branch office in Los Angeles. This new office, which will be managed by P. R. Baus, is located at 7046 Hollywood Blvd., Hollywood 28, Calif.

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Air quench: This involves cooling the part from the critical temperature in open air or with an air blast. It is used on the highly alloyed air hardening steels marketed by various tool steel companies. Very fussy jobs that have to be extremely hard and at the same time must hold their shape as perfectly as possible are treated by this method. Rolls and similar machine parts are occasionally treated in this manner. The average machine designer finds relatively little use for this treatment; most of it is used on tool and die jobs.

INTERRUPTED QUENCH: This method of hardening is generally applied to the through hardening medium and high-carbon steels although it is used occasionally in carburizing. It is best suited to relatively small parts principally to hold distortion and cracking in treating to a minimum and is well adapted to intricate sections. Most of the oil hardening type steels are adaptable to this treatment. The three types of interrupted quench treatments are as follows:

Martempering: This involves quenching (after properly heating the steel to the quenching temperature) into a suitable salt bath which is maintained at a temperature of about 300 to 500 F and holding in the salt quench until the temperature is equalized throughout the piece. The part is then taken out, cooled in air and then drawn to the desired hardness. This permits the structure to change more readily, resulting in less strains than would have been the case if it had been quenched in cool oil. About 3 inches is the maximum cross section that can be fully hardened by this method. It is effective on tool steel parts that have to hold their shape and still have the toughness generally associated with the oil hardening type analyses, alloy gears that require a high hardness with minimum distortion and greater fatigue life, and also on carburized parts where excess distortion might cause trouble.

Austempering: The mechanics of this treatment are similar to Martempering with exception that the steel is quenched in a salt bath which is about 400 to 850 F depending upon the section involved and no subsequent drawing is necessary. It is used on sections usually not over 1-inch and develops hardnesses of about 48 to 55 Rockwell C or about the same hardness as would normally be obtained by drawing to 400 to 850 F with a standard quench-and-draw treatment. Here again distortion is held to a minimum and the treatment usually results in a tougher and

Off in a Jiffy . . .

Your customer makes speed changes quickly with the two-piece QD Sheave.

The rim comes off easily—the pull-up bolts are used as jack screws to break the tapered fit between rim and hub.

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And the QD *stays tight* on the shaft. The cone-friction grip on the hub produces a positive press fit on the shaft. The QD clamps the shaft tighter than any other sheave on the market.

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Specify Worthington Multi-V-Drives, with QD Sheaves and Worthington-Goodyear EC V-Belts. Each strand in the belt carries its equal share of the belt load, as each belt carries its full share of the drive load. (Goodyear EC Cord or Steel Cable V-Belts are used exclusively in Worthington Multi-V-Drives.)

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Whether your products are sorted, heated, or chemically treated the Cambridge Belt designed especially for your continuous handling installation is "Job-Fitted" for maximum performance and operating economy.

Specific metals or alloys . . . certain meshes or weaves . . . are selected from our past engineering experience with the conditions under which your belt must be used.

FREE BOOK describing Cambridge belts for industrial use. 130 pages of valuable data for men concerned with plant operation. Write today for your copy.

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more ductile product than is obtainable by regular quenching and drawing. The process is used mainly on alloy and tool steels of 0.50 per cent carbon or over.

Isothermal: If physical properties similar to that obtainable in small sections by Austempering are desired in larger sizes (up to about 2 inches), this method can be used. It involves quenching into an agitated salt bath at 450 to 600 F, holding there long enough for the temperature of the part to become equalized and then transferring to another bath at a higher heat which serves to draw the piece, *Fig.* 14.

SUBZERO TREATMENT: This is a somewhat controversial method of heat treating and metallurgists differ in their opinions as to the effect on the piece being treated and also as to the mechanics of the method. Reduced to its simplest form it involves transferring a part that has already been treated by conventional heat treating procedure to a very cold medium, such as liquid air or dry ice which exhibits a temperature of minus 100 to minus 120 F. One widely held theory is that the extreme cold forces the internal changes due to treating to completion, thus stabilizing the metal. For this reason tool steel gages which have to maintain accurate size in service under varying conditions are parts most frequently treated in this manner. The only sure way to determine whether a job is adaptable to this cold treatment is to try it.

The application guide shown in TABLE III may serve to highlight some of the points brought out in this discussion of the selection of steels and their heat treatments. It is apparent that no hard and fast rule can be laid down stating that one group of parts should be treated in one manner and another group in another manner. As a matter of fact it is sometimes difficult to decide which is the best treatment for a part even with all the latest and best knowledge of metallurgy at one's fingertips. Frequently different steels and heat treatments have to be actually tried out before the proper combination is discovered, but basic information on steels and their treatments will materially shorten the time necessary to arrive at the proper conclusion.

BUSINESS AND SALES BRIEFS

ELECTED president of Jack & Heintz Precision Industries Inc., Kenneth G. Donald succeeds Byron C. Foy who recently resigned. Mr. Donald will continue as a vice president of Robert Heller & Associates, a Cleveland management engineering firm. Concurrently, the aviation division of the company has opened a branch office in Los Angeles. This new office, which will be managed by P. R. Baus, is located at 7046 Hollywood Blvd., Hollywood 28, Calif.

◆

Federal Machine and Welder Co. has recently announced the purchase of the Warren City Mfg. Co.,

. . . the New Series 1260 General-Purpose Counter

This new 1260 Veeder-Root Counter has the *newsiest* New Look among all things that count . . . a compact, streamlined case of pleasing proportions, finished in rich-looking, 2-tone gray. And this counter features the Veeder-Root "Ease-Eye" Reading Line of six large figures, in large windows, standing out boldly against the contrasting band of light gray.

The new 1260 is designed so that it can be adapted to any of the standard counter drives: ratchet, revolution, direct, or geared, with shaft extending on either side. It will count faster than any standard counter, and is built to give the accuracy and long life you always get from all Veeder-Root Counters.

See how easily this New 1260 can be designed into *your* product . . .
how much it will add to your product's appearance and appeal.

VEEDER-ROOT INC.

HARTFORD 2, CONN.

In Canada: Veeder-Root of Canada, Ltd., 995 St. James St., Montreal 3. *In England:* Veeder-Root Ltd., Dickinson Works, 20 Purley Way, Croydon, Surrey

FOR DEPENDABLE APPLIANCES

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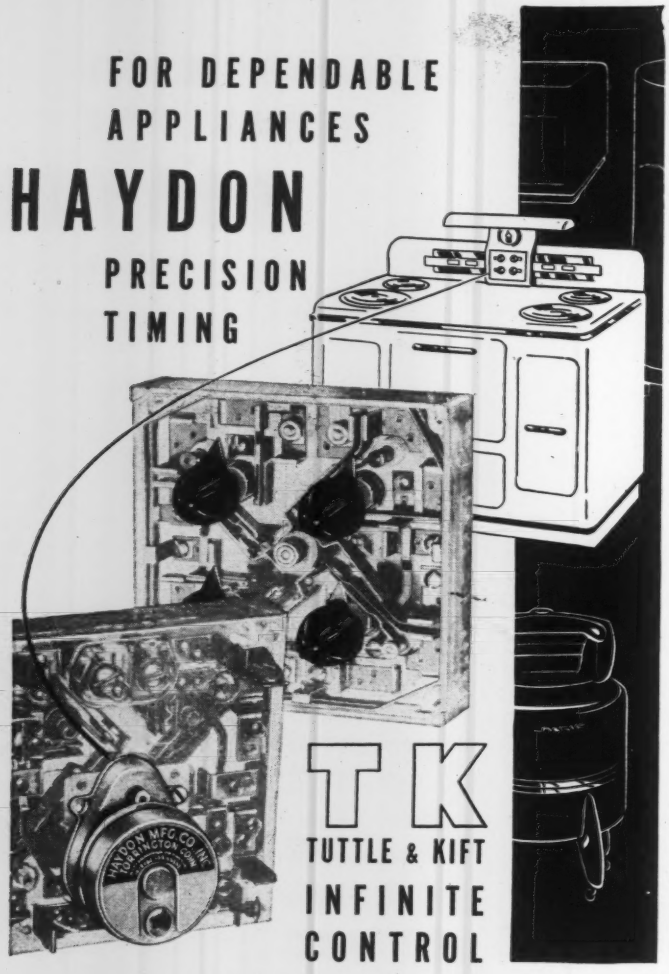
PRECISION TIMING



TK

TUTTLE & KIFT INFINITE CONTROL

Dependable, accurate timing is a key factor in precision appliance components . . . assuring reliable operation and minimum maintenance.

Tuttle and Kift's revolutionary Infinite Control for electric ranges is but one of the many contributions to new appliance developments made possible by Haydon timing devices. A synchronous Haydon motor with a shaft speed of one rpm drives an eccentric cam against four spring contact arms which make and break contact with a second set of parallel arms. The gap between each pair of contacts is easily adjusted by external knobs, varying from 3% to 100% the portion of each cam revolution during the period of contact . . . providing infinite control of heat through control of watts-hours output.

Haydon is equipped to provide manufacturers of appliances and machinery with timing units ranging from synchronous motors to complete timers and controls. Haydon will be pleased to furnish a detailed Engineering and Design Catalog — to submit a design or quotation on specific requirements, either from the factory or at your desk.

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MANUFACTURING COMPANY, INC.

TORRINGTON, CONNECTICUT

HARNESS TIME TO YOUR PRODUCTS

SUBSIDIARY OF GENERAL TIME INSTRUMENTS CORPORATION

Warren, Ohio, from the U. S. Navy. This plant has been operated by Federal Machine and Welder since 1946 when it acquired the stock of the Warren City Mfg. Co. At the same time, announcement was made of the appointment of W. F. Longfield to the post of sales manager of the Warco Press Div. of the company.

◆

Facilities of the Bjorksten Research Laboratories has been increased by the opening of a laboratory and office in Madison, Wis. New office is located at 323 W. Gorham St. Main office and laboratories of the firm remains in Chicago.

◆

Appointment of Dixie Art Supplies Inc., 812 Queen and Crescent Bldg., New Orleans, as a distributor, has been announced by the Craftint Mfg. Co.

◆

Licensing agreement has been made between Lebanon Steel Foundry and the Firth-Vickers Stainless Steels Ltd. for use by the American foundry of the Firth-Vickers centrifugal casting process. This process is used for the manufacture of British turbojet engine parts and is said to make possible complex high-strength parts for operation at high temperature.

◆

Formerly in the general offices of the Berger Mfg. Div., Republic Steel Corp., Gordon Austin has been appointed a salesman in their Philadelphia office.

◆

Recent regional sales supervisory appointments by Eutectic Welding Alloys Corp. include the following: L. D. Richardson in the South-Central states; G. L. Mizell in the Middle and South Atlantic states; W. R. Bajari in the Western states; and P. E. Miller in the Mid East states. Supervising sales in the East Central states will now be J. R. Koske; J. H. Poulson serves in this position in the Eastern states, while R. H. Groman is in charge of the West Central states.

◆

Multimillion dollar plant to be built in Akron, O. by the B. F. Goodrich Co. will be devoted to the manufacture of industrial rubber belting. New plant will have a floor area of 150,000 square feet.

◆

With headquarters in Chicago, T. B. Ellis has been named to head the central district of the General Electric apparatus department. Mr. Ellis, formerly district manager of the industrial division of the company, succeeds R. I. Parker who has been elected a commercial vice president of the company with offices in Chicago.

◆

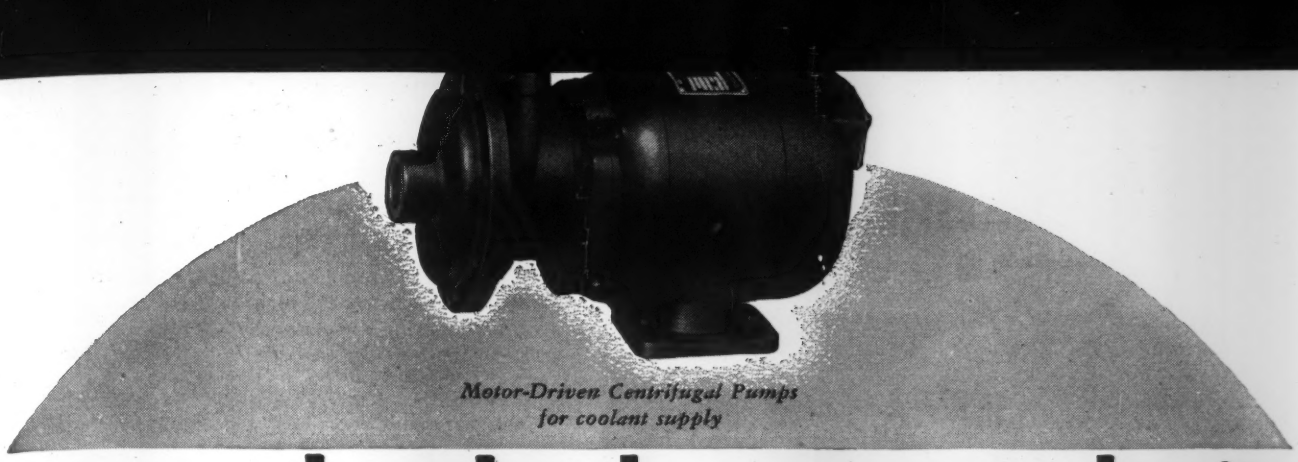
Several new appointments have been made in the sales division of the Reynolds Metals Co. The first has been that of H. N. Kirchdorfer to the post of Eastern division sales manager of the parts division of the company. He will have his office at 10 E. 47th St., New York. In the Nashville, Tenn., area, Wilfred P. Lawless has been named manager, succeeding F. F. Tiffany, who has been named manager of the Dayton, O., sales district.

◆

Acquisition of Walker-Turner Co. Inc. has been announced by Kearney & Trecker Corp. of Milwaukee. The organization will continue its present operation as the Walker-Turner division of Kearney & Trecker.

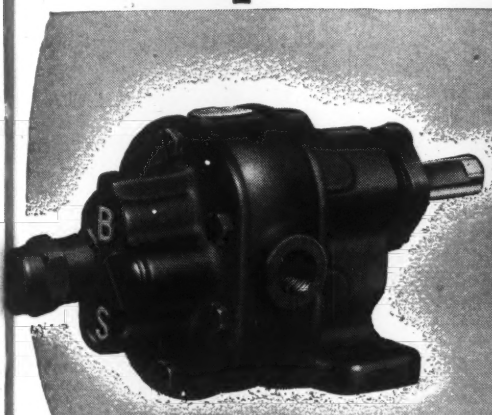
◆

Appointment of Crozier S. Wileman as district sales manager at Wilkes-Barre, Pa. has been announced by

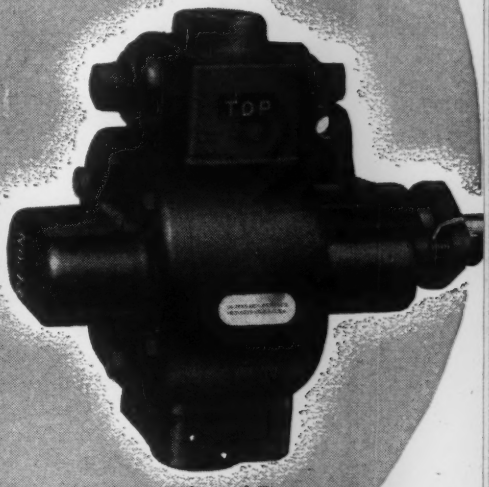


Motor-Driven Centrifugal Pumps for coolant supply

Pumps that back up your design



Rotary Geared Pumps for general purposes



Rotary Geared Pumps Reversible Type for general purposes

Rotary Geared Pumps for hydraulic service

YOU'VE MADE SURE of everything about your machine design . . . including lubrication, coolant supply and hydraulic service. Now make sure that the pumps you specify back up your design—specify Brown & Sharpe Pumps.

Everything about these pumps . . . design, materials and manufacturing . . . is the result of long experience in fulfilling the pump requirements for machine tools and other machine equipment. The aim of Brown & Sharpe in making this complete line of pumps is to provide the correct type of service, a completely dependable service and an enduring service for every pumping need.

Write for pump catalog which gives detailed specifications on the complete line of Rotary Geared, Vane, Centrifugal and Motor Driven Pumps. Brown & Sharpe Mfg. Co., Providence 1, Rhode Island, U. S. A.

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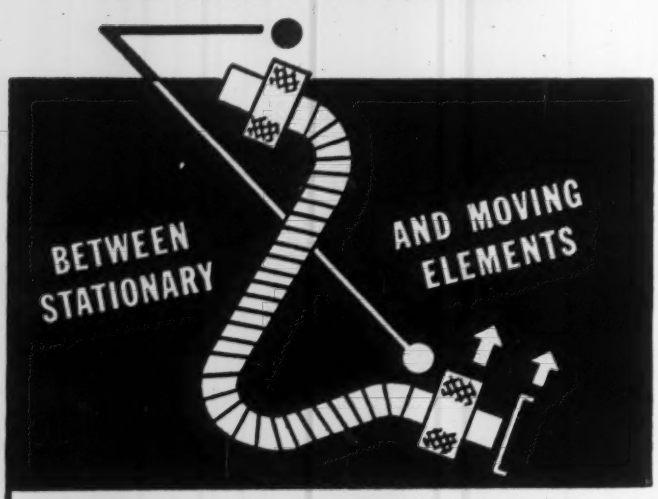


Walker-Turner Flexible Shafting

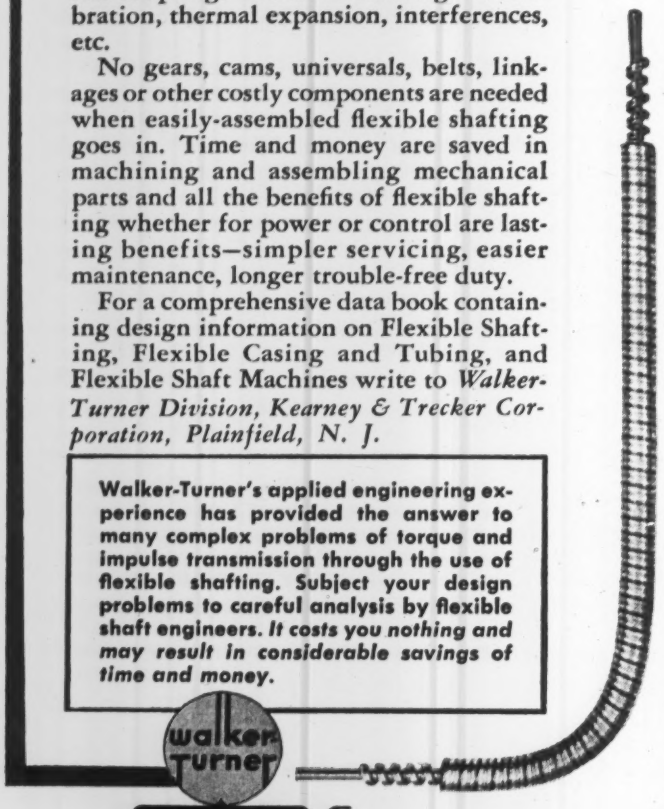
In transmitting power between stationary and moving elements Walker-Turner Flexible Shafting is the shortest distance to efficient operation.

It goes around components, never interferes with other assemblies, yet retains full *direct*-connection sensitivity. Use Walker-Turner Flexible Shafting also to erase the many troubles common to rigid mechanical couplings—troubles resulting from vibration, thermal expansion, interferences, etc.

No gears, cams, universals, belts, linkages or other costly components are needed when easily-assembled flexible shafting goes in. Time and money are saved in machining and assembling mechanical parts and all the benefits of flexible shafting whether for power or control are lasting benefits—simpler servicing, easier maintenance, longer trouble-free duty.

For a comprehensive data book containing design information on Flexible Shafting, Flexible Casing and Tubing, and Flexible Shaft Machines write to *Walker-Turner Division, Kearney & Trecker Corporation, Plainfield, N. J.*

Walker-Turner's applied engineering experience has provided the answer to many complex problems of torque and impulse transmission through the use of flexible shafting. Subject your design problems to careful analysis by flexible shaft engineers. *It costs you nothing and may result in considerable savings of time and money.*



FLEXIBLE SHAFTING

FLEXIBLE SHAFTING
FLEXIBLE CASING AND TUBING
FLEXIBLE SHAFT MACHINES

3466

the Link-Belt Co. He will have his office in the Second National Bank Bldg.

♦

Appointed president and general manager of the Lewis Foundry & Machine Div. of Blaw-Knox Co., Robert W. Frank succeeds F. E. Walling who has resigned. Prior to his present appointment, Mr. Frank was assistant general manager of the division.

♦

The Holtzer-Cabot Div. of the First Industrial Corp. has been purchased by Redmond Co. Inc. The direction of both companies will be assumed by Frank C. Campbell, president of Redmond.

♦

Facilities of the West Electric Products Co., 1796 Pasadena Ave., Los Angeles, has been acquired by Cutler-Hammer Inc. New plant will be integrated with other Cutler-Hammer plants in the manufacture of electric controls and allied apparatus. Los Angeles sales offices of Cutler-Hammer remain at 1331 Santa Fe Ave. At the same time, the company has acquired new quarters for its Dallas, Tex. office and warehouse. New address is 1331 Dragon St., Dallas 2.

♦

Formerly located at the Public Square Bldg., Cleveland, the Gray Iron Founders' Society now occupies offices in the National City Bank Bldg. in the same city.

♦

Robert M. Vilsack has joined the sales department of the Taylor Forge & Pipe Works, operating out of the company's main office in Chicago. Mr. Vilsack was formerly associated with the M. W. Kellogg Co.

♦

Consolidation of the Kingston-Conley Electric Co. of North Plainfield, N. J. with the Hoover Co. has been announced. The Kinston-Conley company will operate as a wholly-owned subsidiary and will be known as the Kingston-Conley Div. of The Hoover Co. Fred S. Kingston, newly elected vice-president of The Hoover Co., will serve as general manager of the division.

♦

Appointment of J. A. Greenland as district manager of its Seattle office has been announced by the De Laval Steam Turbine Co.

♦

Among other appointments of the Penn Electric Switch Co. R. L. Persons has been named manager of the St. Louis territory. At the same time, E. A. Price has been appointed manager of the New York district office succeeding N. E. Jennison who has resigned.

♦

Robert E. Workman, chemical engineer for the Goodyear Tire & Rubber Co. has been named a special representative of the company's newly created chemicals division and will be stationed at St. Louis.

♦

With headquarters in Houston, Tex., Charles E. Shuman has been appointed sales engineer in charge of the Southwest territory by the Cambridge Wire Cloth Co. Area covered by this territory includes Texas, Oklahoma, Arkansas, Louisiana and Mexico.

♦

Formerly sales representative, C. P. Corrigan has been appointed Cleveland district sales manager of the Ramapo Ajax Div. of the American Brake Shoe Co.

♦

Plans for the erection of a new ferro-alloy plant near Marietta, O., have been announced by Electro Metal-

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TO THE LARGEST

Top: Friction element used in textile machinery.
Bottom: Friction disc used as a flange on cable reels.

Looking for a small clutch facing for a high-speed machine tool? **You'll find it in the R/M line!**

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Whatever the size or shape of the friction material you want...whatever its frictional characteristics...R/M probably has it already, or something mighty close to it. R/M brake and clutch materials are made in dimensions from a fraction of an inch in width to 44 inches in diameter. In composition, these materials cover the field from A to Z...from asbestos to zinc!

And...if the friction material you want isn't in stock, R/M can design and make it for you. Behind the R/M representative who calls on you are the facilities of four great plants, four research organizations, and four complete testing laboratories.

Next time you're faced with a problem in design, or supply, of friction materials...get in touch with your R/M representative, or write direct.

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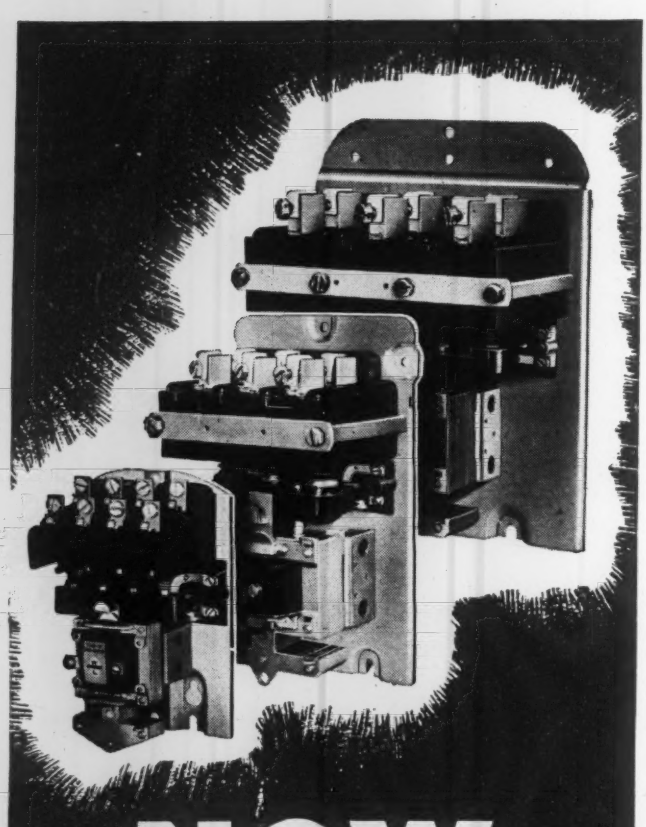
R/M

FIRST IN FRICTION



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Sizes 1, 2 and 3 of Ward Leonard's new Solenoid Contactors are now available

The advantages of Ward Leonard's recently introduced A-C Solenoid contactor can now be obtained in 2 and 3 pole combinations rated up to 100 amperes.

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RESISTORS • RHEOSTATS • RELAYS • CONTROL DEVICES

lurgical Co., a unit of Union Carbide and Carbon Corp. Plant will provide facilities for producing alloys of silicon, manganese and chromium.

♦

Northern Ohio district office of the Allen-Bradley Co. has been moved to 4312 Carnegie Ave., Cleveland 3. District manager is R. J. Roy.

♦

Major expansion program of the Amplex Div. of the Chrysler Corp. has recently been completed. Enlargement and improvement of facilities will permit improved service on oil-cushion bearings and finished machine parts.

♦

Announcement has been made by the Wellman Bronze & Aluminum Co. of the appointment of R. E. Dahlin as Western representative. Mr. Dahlin can be contacted at P. O. 2375 Dallas 1, Tex.

♦

Formerly a development engineer in the laboratories of the General Electric Co., Walter C. Reed has retired and opened a consulting engineering office in Dalton, Mass. Mr. Reed's experience with the General Electric Co. covered the development of solders, brazes and fluxes and their application to production. He also has had wide experience in the design and development of instruments, household appliances and acoustic apparatus.

♦

Chicago sales office has been opened by the Pesco Products Div. of the Borg-Warner Corp. Located at 231 S. LaSalle St., Chicago 4, the offices are under the supervision of J. D. Campbell.

♦

Previously assistant general sales manager of Ampco Metal Inc., S. C. Lawson has been appointed general sales manager succeeding R. J. Thompson. Mr. Thompson has been transferred to California where he will serve as engineering and sales manager of the West Coast territory.

♦

Ray R. West has been named manager of industrial application sales for Minneapolis-Honeywell Regulator Co. He will make his headquarters at the Brown Instrument Co. offices in Philadelphia.

♦

The Belmont Magnesium Foundry, located at Belmont, Calif., has been purchased by Howard Foundry Co. of Chicago. This extends to six the foundries owned by this organization. Appointed sales manager for all six units is William G. Brown, formerly Chicago district manager for Bohn Aluminum and Brass Corp.

♦

Establishment of a sales office in Boston has been announced by the Durant Mfg. Co. The office, located at 1105 Commonwealth Ave., Boston 15, will be under the supervision of J. K. McGinley.

♦

According to a recent announcement, C. A. Hallberg has been appointed division manager for Aro lubricating equipment sales and service in the Kansas City area. Mr. Hallberg will represent the Aro Equipment Corp. in Kansas, Iowa, Nebraska and the western part of Missouri.

♦

Appointment of Lewis P. Naylor as sales manager of Ozalid Div. of General Aniline and Film Corp. has recently been announced. Prior to joining Ozalid, Mr. Naylor was eastern sales manager of the Victor Adding Machine Co.

MEETINGS AND EXPOSITIONS

Nov. 28-Dec. 3—

American Society of Mechanical Engineers. Annual meeting to be held at Hotels Pennsylvania and New Yorker, New York. C. E. Davies, 29 West 39th St., New York 18, N. Y., is secretary.

Nov. 29-Dec. 4—

Eighteenth National Exposition of Power and Mechanical Engineering to be held at Grand Central Palace, New York. Additional information may be obtained from the International Exposition Co., Grand Central Palace, New York 17, N. Y. Charles F. Roth is manager.

Dec. 2-4—

Society for Experimental Stress Analysis. Annual meeting to be held at Hotel Commodore, New York. W. M. Murray, P. O. Box 168, Cambridge 39, Mass., is secretary-treasurer.

Dec. 5-8—

American Society of Refrigerating Engineers. Forty-fourth annual meeting to be held at Hotel Statler, Washington. Further information may be obtained from headquarters of the society, 40 West 40th St., New York 18, N. Y.

Dec. 9-10—

National Warm Air Heating and Air Conditioning Association. Thirty-fifth annual convention to be held at Hotel Cleveland, Cleveland. George Boeddener, 145 Public Sq., Cleveland 14, O., is secretary.

Dec. 13-15—

American Society of Agricultural Engineers. Winter meeting to be held at Stevens Hotel, Chicago. Raymond Olney, St. Joseph, Mich., is secretary.

Jan. 10-14—

Society of Automotive Engineers Inc. Annual meeting and engineering display to be held at Book-Cadillac Hotel, Detroit. John A. C. Warner, 29 West 39th St., New York 18, N. Y., is secretary and general manager.

Jan. 10-14—

American Society of Mechanical Engineers. Materials handling and management divisions meeting to be held at Convention Hall, Philadelphia. C. E. Davies, 29 West 39th St., New York 18, N. Y., is secretary.

Jan. 10-14—

National Materials Handling Show to be held at Convention Hall, Philadelphia, under the joint sponsorship of the Materials Handling Institute and the ASME management and materials handling divisions. Clapp and Poliak Inc., 350 Fifth Ave., New York 1, N. Y., is exposition management.

Jan. 24-27—

Institute of the Aeronautical Sciences. Seventeenth annual meeting to be held at Hotel Astor, New York. Robert R. Dexter, 2 East 64th St., New York 21, N. Y., is secretary.

Jan. 24-28—

American Society of Heating and Ventilating Engineers. Fifty-fifth annual meeting and ninth international exposition to be held at the International Amphitheatre, Chicago. A. V. Hutchinson, 51 Madison Ave., New York 10, N. Y., is secretary of the society and Charles F. Roth, Grand Central Palace, New York 17, N. Y., is exposition manager.

Feb. 13-17—

American Institute of Mining and Metallurgical Engineers. Annual meeting of the Iron and Steel and Institute of Metals divisions to be held in San Francisco. Additional information may be obtained from headquarters of the society, 29 West 39th St., New York 18, N. Y. Ernest Kirkendall is secretary of the metals divisions.

NEW!

Sizes 1, 2 and 3

Ward Leonard a-c Magnetic Starter Is Small in Size, Big in Performance

For fast, positive, dependable across-the-line starting of non-reversing motors, install Ward Leonard 4110 a-c Magnetic Starters.

Unit construction. Open or enclosed type. Accessible components. Double-break silver - to - silver main contacts Thermal relays give overload protection. Local or remote control.

Ward Leonard Starters are "Result-Engineered." By modifying a basic design, Ward Leonard can give you the results of a special . . . for the cost of a standard.

Write for Bulletin 4110. Ward Leonard Electric Co., 58 South St., Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada.

WHERE BASIC DESIGNS IN ELECTRIC CONTROLS ARE RESULT-ENGINEERED FOR YOU

WARD LEONARD ELECTRIC COMPANY

RESISTORS • RHEOSTATS • RELAYS • CONTROL DEVICES

Briggs & Stratton Engines — America's Choice for Thirty Years

For 30 years Briggs & Stratton 4-cycle air-cooled engines have proven their value, performance, and dependability under the most exacting conditions.

Users, manufacturers, and dealers *know* that equipment powered with these engines is powered RIGHT.

This public confidence has resulted from the engineering leadership, unending research, and the skill of Briggs & Stratton workmen — all directed at making the world's finest single cylinder, 4-cycle gasoline engines.

BRIGGS & STRATTON CORPORATION
Milwaukee 1, Wisconsin, U. S. A.

DESIGN ABSTRACTS

Problems of V-2 Assembly

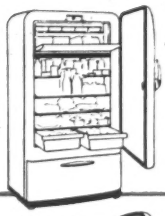
V-2 rockets used at the White Sands Proving Ground are copied as closely as possible from the German prototype as to weight, weight distribution, and overall dimensions. But the rocket is filled with elaborate instrumentation to record phenomena that have been, until now, far beyond the range of man's knowledge.

First modification has been to increase height reached by altering the German V-2's trajectory. A new nose tip was designed to house experimental and test equipment. The nose section was also changed to take cosmic ray counters, a solar spectrograph etc.; the body of the rocket was sealed at one atmosphere at ground level and housed electronic equipment, batteries, and ground controls used prior to launching. A radio system which permitted an operator on the ground to cut off the fuel supply was an adaptation of the five-channel FM control system developed during the war. It is so designed that three channels must be closed before cutoff is accomplished, minimizing unintentional cutoff of fuel due to electronic disturbances.

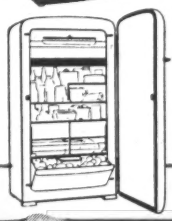
Details Are Incomplete

Complete details of the German V-2 rocket have never been assembled, and most of our knowledge of the weapon came from examination of damaged parts, interviews with captured German technicians, and manuals, but only four launchings of the first 25 rockets were failures. From all the V-2 parts collected by Army and Navy technical intelligence personnel overseas and shipped home, only two complete rockets could be assembled. Despite interrogation of German personnel and examination of German specifications and drawings, complete technical data on all the components are unavailable. Parts were carefully examined and analyzed for chemical composition of materials, dimensions, and workmanship. In one case more than 40 manufacturers were contacted before one was found who could produce a part with metric dimensions.

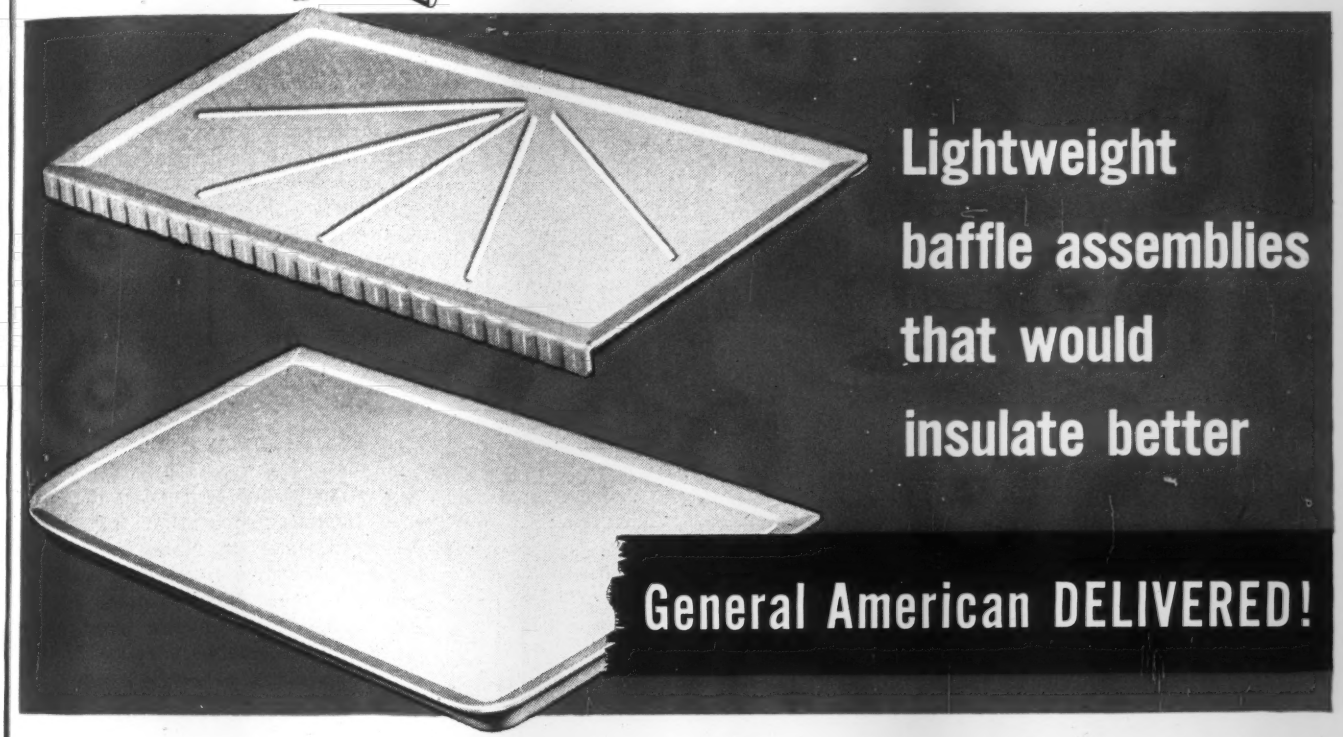
One failure was caused because a graphite vane disintegrated soon after launching. The rocket headed off east instead of north, but the



COOLERATOR and



KELVINATOR needed:



A baffle assembly has a tough insulating job to perform. It separates the deepfreezing section of the refrigerator from the food storage compartment, and is constantly subject to temperature extremes as well as rust and chipping from constant use.

General American designed a new type of baffle assembly that provides more efficient insulation, prevents rust, eliminates chipping and costs less to produce than the old type. From dies built by General American, these baffle assemblies were molded on a 32 oz. injection press. General American handled even the end operations, which consisted of cementing and—with the Kelvinator—filling the baffle assembly with fiber glass insulation.

General American customers benefit from more than 40 years of precision production experience. Modern high-speed equipment—2 to 32 oz. injection presses and 100 to 2000 ton compression presses—enables General American Plastics to turn out any type of plastics part or product quickly and economically.

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LEBANON ALLOY AND STEEL Castings

CIRCLE L

fuel was cut off from the ground control station. Another exploded at 28,000 ft, 27 sec following takeoff. Visual inspection of the wreck indicated that an outboard bearing overheated and this caused the fuel tanks to let go.

Steering failures accounted for several unsuccessful launchings. German technicians, however, explained that they had faced similar types of trouble during the last phases of the war. One of the two gyroscopes which control the V-2 prevents roll and provides control in the azimuth. The other, a pitch-control unit, controls trajectory during the burning period. Their axes maintain the direction in which the rocket was aligned during the burning period, and in flight maintain this direction, one along the rocket axis, and the other horizontal and perpendicular to the direction of the target.

Deviations are detected by potentiometers which furnish control voltages to electrical-hydraulic servos.—*From a paper by Lt. Col. W. L. Clay, Ordnance Dept., presented at a meeting of the Detroit section of SAE.*

Molybdenum for High Temperature

MOLYBDENUM presents a tantalizing combination of properties to those interested in operating temperatures above the melting points of the heat-resisting alloys. Among the high-melting point metals it is outstanding because of the relatively large potential supply. It melts at about 4750 F. In some of its impure or alloyed forms it resists plastic flow, or creep, and has enough strength at very high temperatures for a number of uses. Yet, if exposed without protection in an oxidizing atmosphere, even at temperatures far below its melting point, it may literally disappear. The metal oxidizes easily at high temperatures, and the oxide is volatile, so that unless oxygen is kept away from the molybdenum the metal article may vanish, and be found only in the form of the oxide precipitated at comparatively cool and possibly remote locations through process of sublimation.

An obvious way to take advantage of the desirable features of molybdenum, and to make it useful for ultrahigh temperature service, is to apply a coating that will protect it from oxygen in the atmosphere. Results of various tests indicate that the oxidation of the molybdenum was greatly retarded by the best of several ceramic coatings tried. In an air atmosphere, at 1650 F, unprotected molybdenum sheet was found to de-

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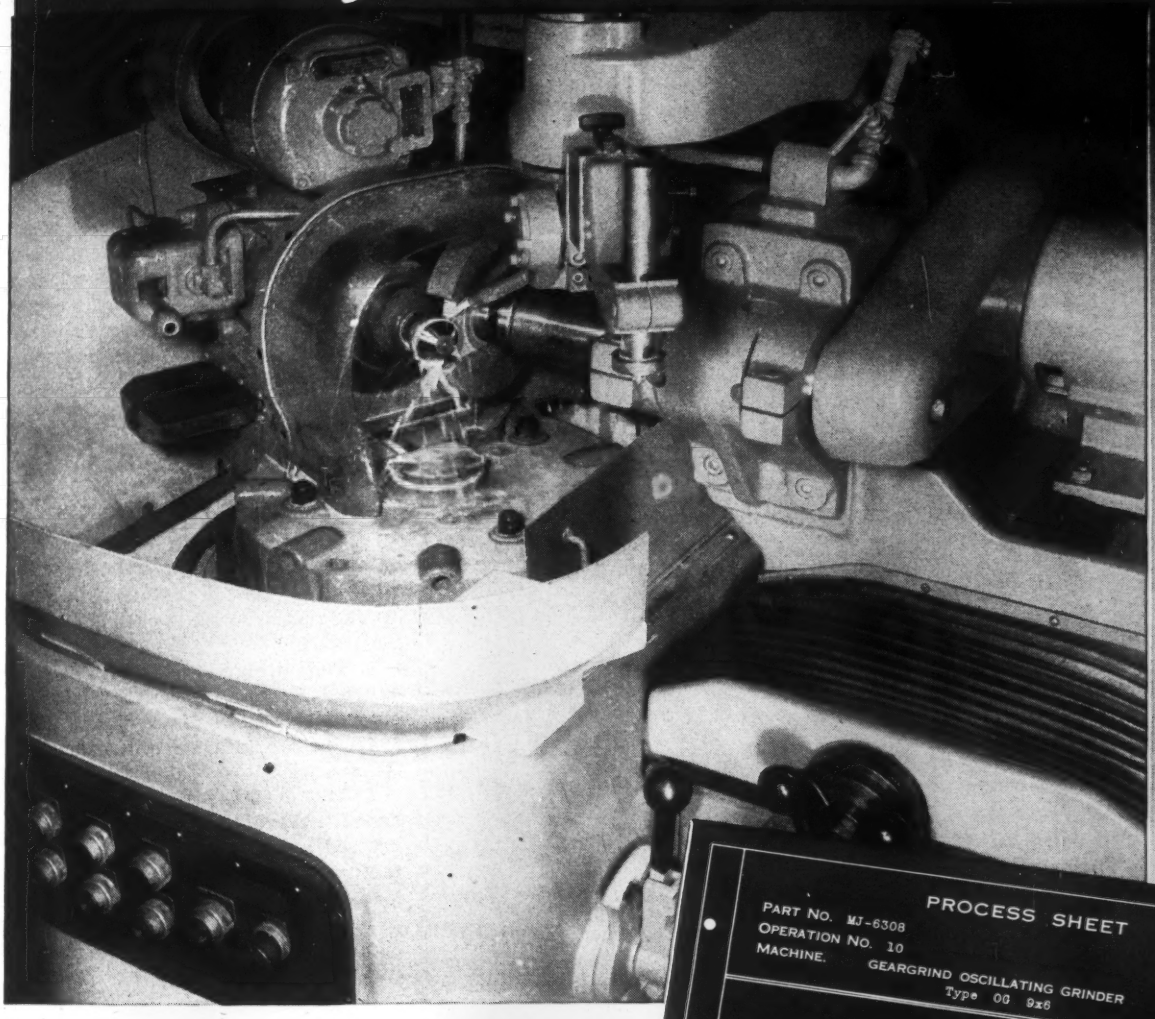

Automatic feed takes the Geargrind Universal Oscillating Precision Grinder out of the tool room or experimental shop and puts it in the production line.

It delivers extreme accuracy and fine finish at lower costs. It may be equipped to handle production grinding of any of the following types: generated external and internal spherical surfaces, annular ball bearing races and barrel shaped surfaces.

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Operation: Grinding spherical surface.
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Finish: 12 micro.
Pieces per Hour: 53, at 85% efficiency.

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For continuous use, driving smaller size hex socket screws. Blade adjustable, reversible and renewable. Speeds assembly and cuts cost.

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crease in thickness 0.02-in. in ½-hr, whereas there was no decrease for ceramic coated molybdenum heated for 70 hr under the same conditions.

At a gas temperature approximating 3500 F, giving a surface temperature on a specimen of 2600 F or more, only short-time protection of the molybdenum was attained. The oxidation rate at these high temperatures was found, however, to be sufficiently retarded by the presence of the ceramic coating to make the use of coated molybdenum feasible for special high-temperature applications in which prolonged service is not required.

One current use of the new coating is to protect molybdenum pitot tubes which are built into the nozzle end of ram-jet engines of a type used for pilotless aircraft. These tubes, which are subjected to a gas temperature of about 3000 F, are expendable and need not last over 5 min. Test of a coated tube under these conditions indicated a life in excess of 45 min.—*From a paper by W. N. Harrison, National Bureau of Standards, presented at a recent SAE meeting.*

Styling the Studebaker

THE art of styling passenger car bodies, as practiced at South Bend, is an orderly, step-by-step process:

1. The design staff is given an explanation of the design problem, blueprints of the chassis, and specifications for interior dimensions and clearances.

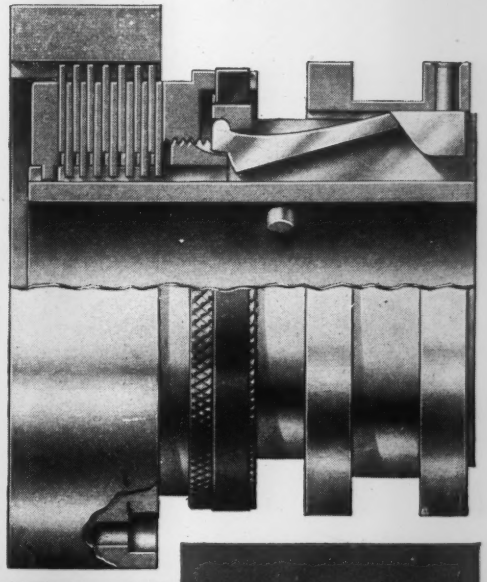
2. The design philosophy is established according to new ideas expressed by management, other manufacturers, and the public. The new ideas are combined with two eternal concepts: Weight is the stylist's enemy. The car must have styled-in forward motion to appear fast even when stationary.

3. Tasks are assigned to groups of designers. One group may do rough sketches of the entire car. Another group may work on the front and rear ends only. Other groups concentrate on other units. Results of their work are piles of rough sketches and several ⅛-size clay models. Designers are allowed to work in pencil or clay, as they choose, and together they assemble enough ideas for half a dozen cars.

4. Most promising designs are selected from the roughs. A good front treatment may be tried with a likely side elevation, or other combinations tried. Four or five of the resulting designs are sketched and modeled in clay to one-quarter scale.

5. Satisfactory clay models are

MAXITORQ



KEEPS GOOD COMPANY

Shown above are the Maxitorq Floating Disc Clutch and the modern Steve-Krane Stevadore 5 ton capacity Crane, manufactured by the Silent Hoist & Crane Co., Brooklyn, N. Y.

The Maxitorq is inside the winch and transmits the power for Hoisting and Lowering for the load line.

Here's a further instance of the fast growing adoption of Maxitorq Clutches by nationally known manufacturers.

Other product or machine designers, manufacturers of machine tools or machinery may also find that Maxitorq has the "extra" features they need.

For instance . . . compact, streamline design; patented Separator Springs that keep discs apart in neutral . . . no drag, abrasion or heating. No tools needed for assembly, adjustment, take-apart. Shipped completely assembled ready to slip onto a shaft. Capacities to 15 H.P. at 100 r.p.m., wet, dry, single or double.

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HOW TO RECOGNIZE A JOB FOR HARD RUBBER

How can a man think straight about materials when so many new ones are always popping up. Now take hard rubber, for instance.

It's been all around us for nearly a century. Let's clamp down on our hard rubber pipe bits, ease ourselves down on our rubber casters, and take a good look. From an impartial viewpoint. *(We* can, because Ace molds *both* hard rubber and other important plastics).

First, we see dozens of grades of hard rubber, and they're all different. Generally speaking, they're black beauties, easily polished, with a real nice feel. *Good* for handles, grips, pipe bits, knobs, combs, etc.

We see it's tough, stable stuff that's well nigh impervious to water and 'most all known chemicals. (Except mineral oils and organic solvents– but Ace *synthetics* take care of them.) Its resistance to water is topped only by Ace polyethylene.

Tensile strength of hard rubber is up with the best plastics–up to 9,700 psi. Coefficient of expansion is very low–good for refrigerator parts. For the hot spots, we can give you compounds that won't distort up to 250° F., but don't count on more than 150° from any general purpose mix.

You probably know all about the top-notch electrical properties of hard rubber. But did you know its wear resistance is so good it's often used in bearings? So tough it's used in bowling balls.

Add it all up–Ace hard rubber is good for a lot of things– water meter parts, magneto parts, foot tubs, vinegar dumpers, fountain pen parts, sparges (if you know what *they* are) and chemical piping. It's probably natural for a lot of things you make, too.

Want to know more? Just tell me your problems or ask for a copy of our new Hard Rubber and Plastics Handbook.

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cast in plaster and the plaster replicas are painted, trimmed with bumpers, door handles, and lucite headlights. Photographs of completed models are projected full-car size on screens so that the cars can appear to rest on ground. This procedure shows how production cars would look, without the cost of full-size mockups.

6. The best designs are chosen from the full-size projections and fashioned full-size in clay. Any distortions incurred in scaling up are corrected. Then plaster or wood mockups are built, painted, trimmed, equipped, and glazed to look like production jobs. All mockups to be shown together are painted the same color to eliminate color prejudices.

Plaster mockups cost less, but wood mockups are more realistic because doors open and interiors can be finished.

7. Management makes the decision on the basis of the mockups. Spectators are assembled about 150 ft away from a veiled full-size model. Then the model is revealed to them suddenly in normal daylight. Here's where first impressions count; the design that looks alive on the first glance is the wise choice.

If management suggests changes—and inevitably it does—another showing is given after the changes have been made. Then, at last, the final decision on design is made.—*From a paper by Raymond Loewy, presented at a meeting of the Detroit section of SAE.*

Remote Control Engineering

THERE is hardly any research today involving nuclear science which does not involve remote control operations to some extent. Perhaps it is a simple operation such as transferring a radioactive sample from a lead pot to an improvised shielded area by means of a set of long tongs. The activity may not be large, but, if spilled, might enter the human body through a cut, via the air, or orally, and ultimately cause serious radiation damage. Less seriously, the accident might contaminate valuable apparatus and thus slow up or prevent completion of the research. It is obvious that the tongs used for this simple "hot" operation must have properties not required in, say, foundry tongs.

Some of the remote control devices already in use are several types of tongs, small over-the-wall hand manipulators, periscopes, a vertical can opener, remote control gages, drilling devices and a synchro operated syringe. No program in the development of remote control engineering has yet been set up which will even approxi-

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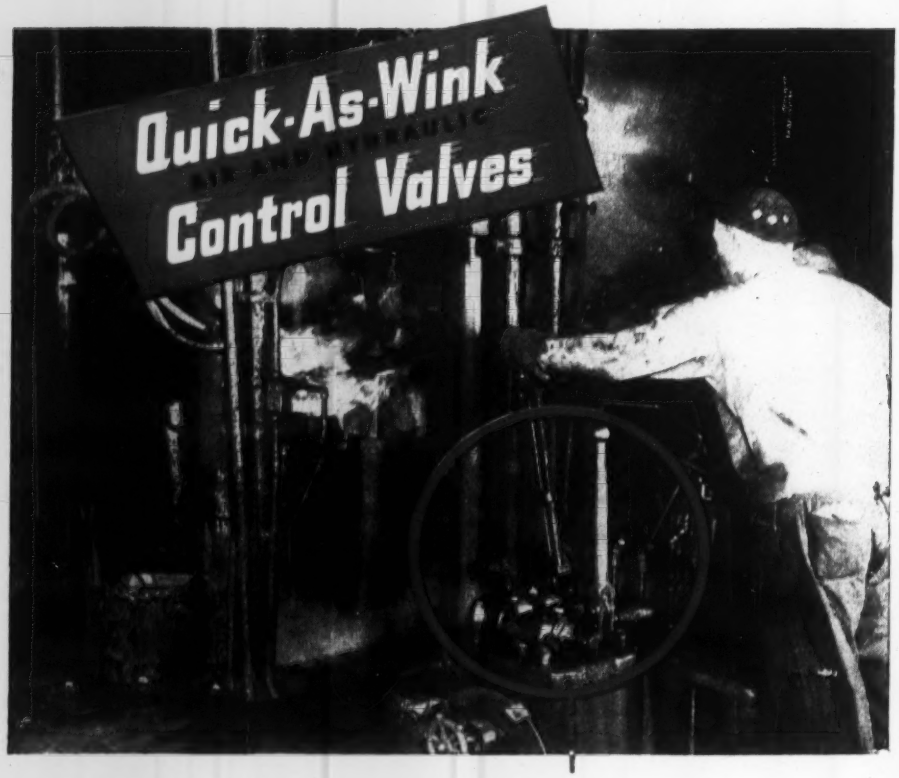

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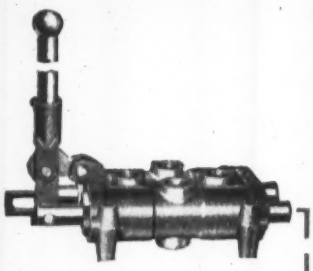
Positive and fast acting with U-shaped packers that are expanded by the pressure, Quick-As-Wink Control Valves seal tightly preventing leakage and bleeding. All operating parts are in pressure balance eliminating any tendency to creep or crawl. There is no lapping—no grinding—no metal to metal seating. Every valve is a high quality control—precision made—and individually tested before being shipped. This assures users a maximum of long, efficient, trouble-free service.

Furnished in hand, foot, pilot, solenoid and diaphragm operated designs for controlling all types of air and hydraulic equipment. Let us work with you on your requirements!



Quick-As-Wink Lever Operated Hydraulic Valves

The MF-651-N4 pictured above is a four-way neutral position valve, for controlling double acting cylinders. It can also be furnished with three position "compound-exhaust", or "compound-on" actions. Recommended for use with oil or water up to 150° F. and 2000 PSI. Other types for pressures up to 5000 PSI, —but send for a catalog today and get *full* details about the *complete* line.

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mate the needs of the research worker in atomic energy now and in the future. Scientists will want to handle ever-increasing amounts of radioactivity and to do ever-increasingly difficult experiments with radioactive materials. The urge to produce an automaton should no longer be for spectacular exhibitions only, but for very practical needs. The speed with which nuclear research goes on will, in the future, depend on the speed in the development of remote control engineering. Certainly this field is at the present time only in its infancy —if it has really been born.—*From a talk by O. C. Simpson, associate director, chemical division, Argonne National Laboratory, given at the semiannual meeting of ASME in Milwaukee.*

Early Wire Making

ALTHOUGH wire was first produced by hammering, shearing and soldering, production by drawing, essentially in its present form, has been practiced since the Middle Ages. It has been established that about 1000 AD the use of tapered holes in hard plates had developed into the actual drawing of soft metals, but probably not of iron. In the period between 1300 and 1350 the wire drawing process was extended to cover iron, and by 1430 iron wire was made essentially as it is today.

From the start the wire business has evidently been a complicated and specialized industry. Bonzel quotes a thirteenth century ordinance of the City of Paris:

> Whosoever would enter the wire business, it is required of him that he know the trade, and that he have what it takes.

The town records of Coventry, England, in 1430 give the names of the members of a Wire Workers Guild, listing the members as rod makers, annealers, coarse-wire drawers and fine-wire drawers. Five years later, September 14, 1435, there is an entry on the town record which is probably the earliest record of a customer complaint in the wire industry. It reads:

> Sir, I had of you of late bad wire:
> Sir, amend your hand, or in faith
> I will not more buy of you.

From a paper by H. A. Caldwell, chief metallurgist, Tennessee Coal, Iron and Railroad Co., and C. L. McGowan, superintendent, wire mill, Atlantic Steel Co., presented at a regional meeting of the AISI in Birmingham, Alabama.

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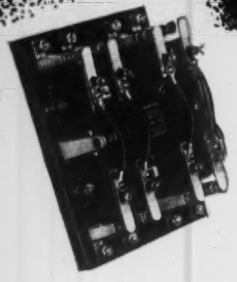

Application:

For automatic control systems such as (a) maintaining circuit control regardless of momentary interruption in control line due either to low voltage or associated relay operating time; (b) providing "memory" circuits and to permit preset control operations.

Mechanically held relays are ideal for control systems for many machine tools, processes, furnaces, etc. They are also essential in any application where alternating current hum cannot be tolerated.

Ratings:

This is a NEW LINE of Multi-Contact Relays, available as follows: 10 ampere to 12 pole normally open and 12 pole normally closed or any combination of normally open and normally closed poles. 550 volt AC maximum.

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Features:

Mechanically locked, not latched. Action is through a single solenoid with integral control contacts permitting circuit connections equivalent to a two-coil unit.

Wiping and adjustable contacts for reliable service at milliamperes of load at low voltage or at full rating.

There, in a nutshell, are the essentials of these new ASCO Mechanically Held, Electrically Operated Relays. Do they appear to fit into your assembly picture? Or is there some other type that you need? We have many different Relays and will be glad to work with you on your problem. Write us in detail.

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Commercial

ROLLER GRILL. For heating frankfurters, which rest on revolving stainless steel rollers. Three-stage heat control. Flight Mechanical Laboratories, Long Island City, N. Y.

Earth Moving

REAR-DUMP ROCK WAGON. For carting and dumping rock, dirt and bulk materials. Capacity, 16.5 yards. Electric power steering; 90-degree turning radius. Dumps by electric motor and cable. Forward speeds, 2.19 to 17.3 mph; reverse speeds, 2.19 to 4.38 mph. Four-wheel multiple-disk air brakes; 21 by 25 tapered bead tires. Weight, 28,500 lb. R. G. LeTourneau, Inc., Peoria, Ill.

Heat Treating

RESISTANCE HEATING MACHINE. For localized annealing of truck transmission shifter shafts. Is single-station, air-operated type; consists of fabricated steel framework supporting pneumatically operated work clamps connected to a 50-kva resistance-heating transformer. Clamps, dies and transformer are water cooled; solenoid water valve turns off water when machine stops. Agnew Electric Co., Milford, Mich.

Industrial

WARM-AIR SPACE HEATER. Coal-fired, can be converted for firing with gas or oil. For industrial use. Stainless steel combustion chamber. Two capacities: 1,250,000 and 1,500,000 Btu per hr. Can be used with or without ducts. Operation of fans and stoker completely automatic, controlled by room-temperature thermostats. Dravo Corp., Pittsburgh.

HUMIDIFIER. Automatic; portable. Humidistat controlled; rain-drop dripper system filters, washes and moistens the air. Water continuously recirculated from 3-gallon reservoir by small centrifugal direct-driven pump. Unit disperses

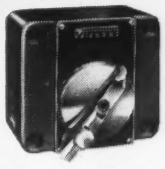
New and Improved VICKERS PRODUCTS

For Better Hydraulic Machinery

The Vickers units illustrated below are either new products or have recently been improved. Among their advantages are small size, and many have gasket mounting for even more compact hydraulic installations. For information regarding any of these new or improved units, ask for the Data Sheet or Bulletin number indicated.

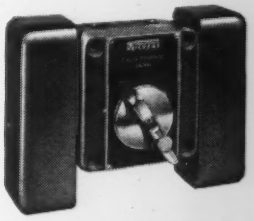
VICKERS CHECK VALVE (In-Line Type)

For working pressures up to 3000 psi, this compact check valve can be furnished for piping sizes ¼", ¾" and 1½". Data Sheet 113720.



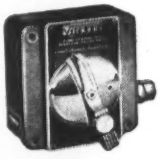
VICKERS FLOW CONTROL VALVE

Accurate control of oil flow in hydraulic systems (independent of pressure variation) can be obtained with this compact, gasket mounted unit. Bulletin 45-35.



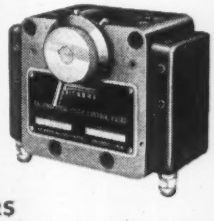
VICKERS CYCLE CONTROL PANEL (Solenoid Operated)

A compact unit for controlling rapid traverse and adjustable feed cycles with fully remote electrical cycle timing. Data Sheet 109164.



VICKERS FLOW CONTROL AND OVERLOAD RELIEF VALVE

Compact metering valve incorporates the Vickers patented flow control and relief valve for regulation of oil flow and pressure. Bulletin 48-36.

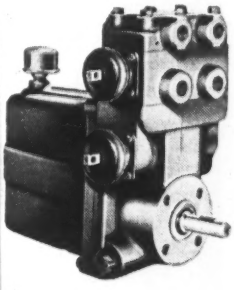


VICKERS RECIPROCATING CYCLE PANEL

For reciprocating cycles of machine tool carriages, etc., with accurate and selective reversal control. Data Sheet 80803.

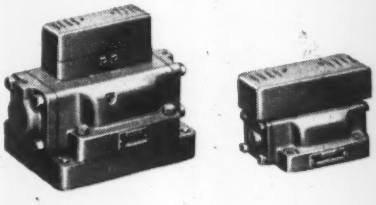
VICKERS PRESSURE SWITCH

Available in two models for pressure ranges 100-2000 and 500-3500 psi with independent pressure differential adjustment. Data Sheet 113929.



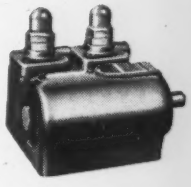
VICKERS POWER PACK

Vane type hydraulic pump, overload relief valve, oil tank, filter and operating valve are included in this low priced unit. Bulletin 46-48a.



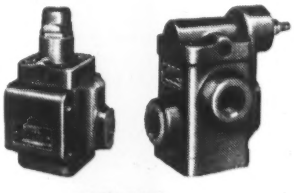
VICKERS SOLENOID OPERATED CONTROL VALVES

Compactness, simplified installation and minimum piping are but a few of many features. Bulletin 48-27.



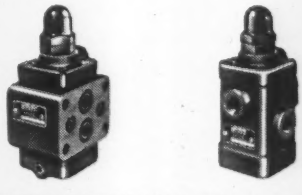
VICKERS TWO PRESSURE PUMP (Small)

Two vane type pumps and integral automatic valving, all combined in this compact unit, providing high-low pressure pumping action. Data Sheet 117994.



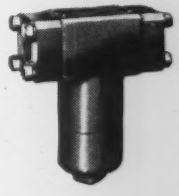
VICKERS PRESSURE REDUCING VALVES

Maintain accurate reduced pressure; available with integral free return flow check valve, gasket and screw connections. Data Sheets 101885, 100165.



VICKERS PRESSURE SEQUENCE CONTROL VALVES

These new sequence valves are available for smaller piping sizes, and are arranged either for gasket mounting or threaded-connections. Bulletin 45-34a.



VICKERS PROPORTIONAL OIL FILTER

This compact filter provides continuous micronic filtering for hydraulic systems at pressures up to 3000 psi. Bulletin 47-50.

3671

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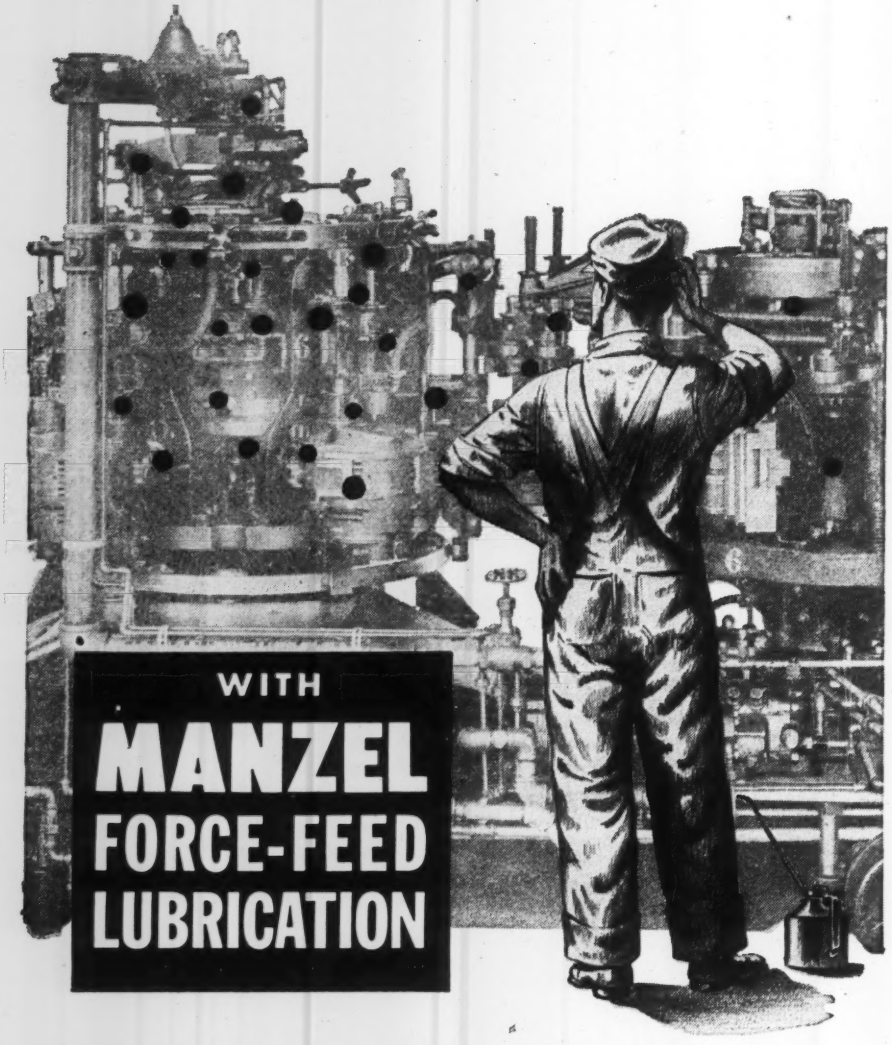
CORRECT THESE SPOTS BEFORE HIS EYES!



MANY spots requiring many different amounts of lubricant make it easy for a new man (or even an experienced one) to get all mixed up.

Manzel Force Feed Lubricators eliminate not only the confusion—but also the workman. For Manzels automatically lubricate any number of wearing points—no matter how hard to get at. Just enough of the right type of lubricant is always at each point.

Manzel Force Feed Lubricators save the initial cost many times over each year. They are supplied as standard equipment on various makes of engines, pumps, compressors, and other heavy machinery. Or they can be installed on your present equipment.

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276 Babcock Street Buffalo 10, N. Y.

12,000 cu ft washed air per hour. Palmer Mfg. Corp., Phoenix, Ariz.

WEIGHING SCALE DIAL UNIT. Positive pointer drive mechanism uses high-strength, noncorrosive special alloy tapes to replace conventional rack and pinion. Adjustable, self-compensating hydraulic dashpot controls pointer action and prevents shocks from reaching mechanism. The Howe Scale Co., Rutland, Vt.

HUMIDIFIER. Vaporizes over ½ gallon of water per hour. Water flow level regulated by automatic float assembly; 60-watt motor wired in series with humidistat. Height, 10½-in.; width, 13½-in. Walton Laboratories, Inc., Irvington, N. J.

Manufacturing

PORTABLE TAPPERS. Pneumatic, push-pull type. Automatically reversible. Suitable for tapping up to ¼-in. capacity in ⅛-in. sheet steel and for cleaning up to ⅜-in. tapped holes. New type Jacobs tapping chuck. Aro Equipment Corp., Bryan, O.

ALL-PURPOSE SHEAR. For cutting metallic and nonmetallic sheet. Lower tool stationary while upper tool, which is spring loaded, reciprocates vertically. Cutting speeds, 10 to 40 ft per min. Frame is welded heavy steel plate. Elge Associates, New York.

HYDRAULIC TURRET PRESS. Turret table mounts fixtures for blanking, forming, drawing, swedging, assembling, etc. Table operated manually while press can be operated manually or automatically. No packing in hydraulic pump unit which is self-contained. Press equipped with load gage, electric limit control, electric overload control, and magnetic power valve submerged in oil. Universal Airline Joint Mfg. Co., Lafayette, Ind.

MULTIPURPOSE TOOL. Portable; electric. Will grind, polish, drill and cut by change of spindle attachments. Motor, 115-volt ac-dc, single-phase; speed, approx. 3000 rpm no load, 2000 rpm normal load; weight, 5 lb 13 oz. Porter-Cable Machine Co., Syracuse, N. Y.

HYDRAULIC PRESS. Two-column type. Capacity, 10 to 200 tons. Can be converted to wide range of operations in metal, plastics, ceramics, and powders. Single or multiple ram action. Hufford Machine Works, Inc., Redondo Beach, Calif.

HYDRAULIC PRESS. Capacity, 2000 lb. Ram stroke, ram speed and ram pressure easily regulated by conveniently located controls. Operator must depress two levers before ram will descend. Overall size, 13 by 30 by 29¾ inches; weight, 270

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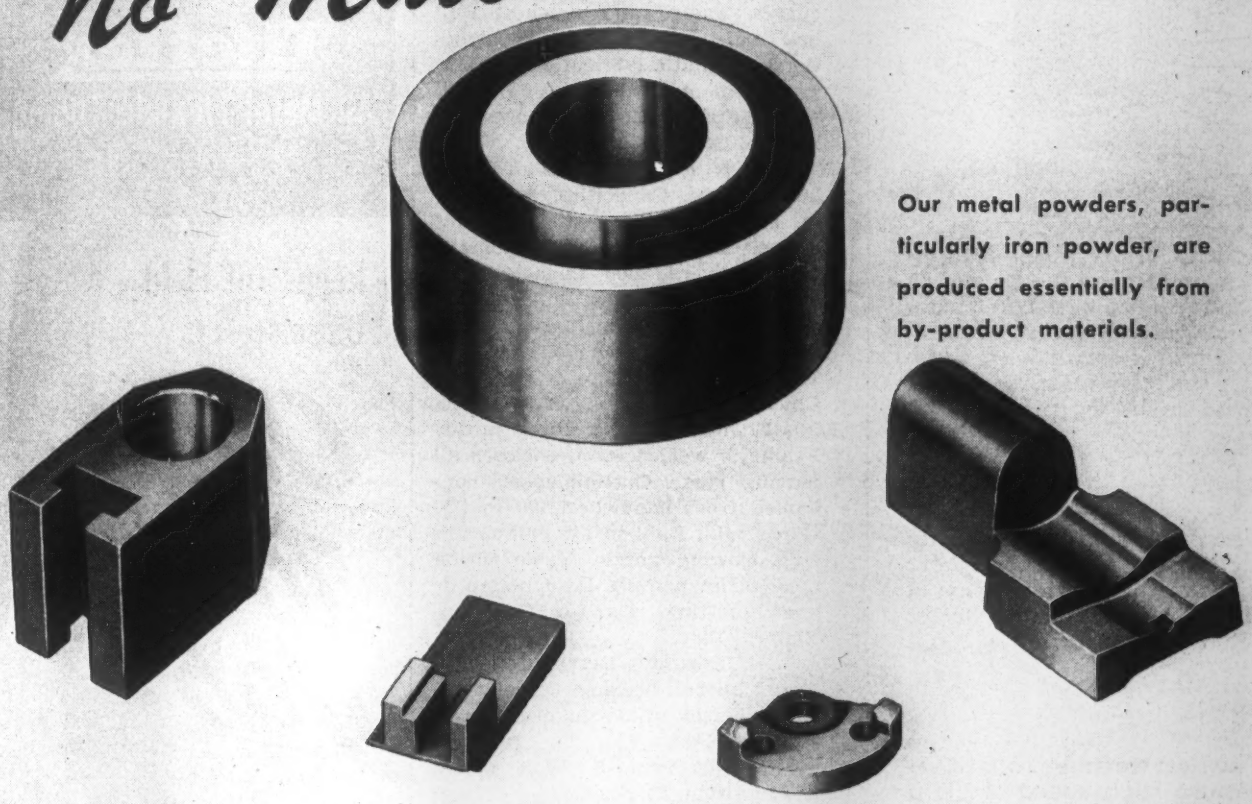

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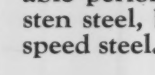
AMPLEX MANUFACTURING CO. DETROIT 31, MICHIGAN

Division of Chrysler Corporation

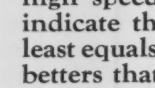
FIELD ENGINEERS AND OILITE BEARING DEPOTS IN PRINCIPAL CITIES

facts speak LOUDEST

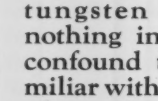
At least one type of Molybdenum high speed steel is listed and promoted on a basis of equivalent and interchangeable performance with tungsten steel, by makers of high speed steel.



Users' reports of Molybdenum high speed tools *everywhere* indicate that performance at least equals and in many cases betters that of tungsten tools.



The heat treatment of Molybdenum high speed steels is basically the same as that of tungsten steels. There is nothing in the treatment to confound those who are familiar with the heat treatment of tungsten types.



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HS.2 MD-11

lb. The Denison Engineering Co., Columbus, O.

SHEAR. Bench type, hand powered. Can cut up to 16-gage sheet steel. Has gravity chute, protracting gage, material gage, adjustable stops, and adjustable bearings. O'Neil-Irwin Mfg. Co., Lake City, Minn.

PORTABLE ELECTRIC SHEAR. Cuts 18-gage mild hot-rolled steel up to 15 ft per min. Can cut in straight line, curves, angles and notches. Full ball and roller bearing construction; automatic lubrication of plunger from gear housing. Weight, 4¾ lb. Stanley Electric Tools, New Britain, Conn.

ELECTRIC NUT SETTERS. High-speed, impact type. Capacities, ⅜ to ¾-in. bolts. Are torqueless; at point of resistance impact unit automatically delivers 3000 impact blows per minute, tightens to torque of over 200 lb-ft; is instantly reversible. Unit is 12½ in. long, weighs 14½ lb. Illinois Gage & Mfg. Co., Chicago.

BAND FILING MACHINE. Floor model. Frame is welded steel, encloses all moving parts. Cutting speed, controlled from handwheel, 50 to 250 ft per min. Built-in air pump with chip blowing nozzle. Table tilting mechanism permits level, miter or angle cutting. DoALL Co., Des Plaines, Ill.

PORTABLE ELECTRIC DRILL. Capacity, ¼-in.; all ball bearing. Offset spindle enhances utility in close quarters. Weight, 4⅜ lb; full-load speed, 1400 rpm. S. Wolf & Co. Ltd., London, England.

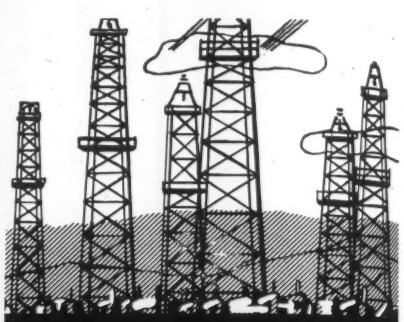
PORTABLE ELECTRIC DRILL. Capacity, ½-in. Ventilated through large slotted ports. Highly polished die-cast case; free speed, 500 rpm; removable dead handle; steel bearing inserts; removable switch handle; precision gearing; 3-jaw Jacobs key type chuck. Length, 11 in.; weight, 7 lb. Independent Pneumatic Tool Co., Aurora, Ill.

Materials Handling

MOBILE CRANE. Capacity, 45 tons at 12-ft radius. Powered by two diesel engines; is rubber tired. Carrier has welded frame with multiple straight-beam construction for side members. Telescopic outriggers used with screw jacks and floats. Five forward speeds up to 18 mph; one reverse speed. Rear axles mounted on equalizer beams. Power from engine transmitted to turntable through hydraulic coupling. Thew Shovel Co., Lorain, O.

Metalworking

THREAD MILLING MACHINE. Single cutter type. Work and cutter spin-



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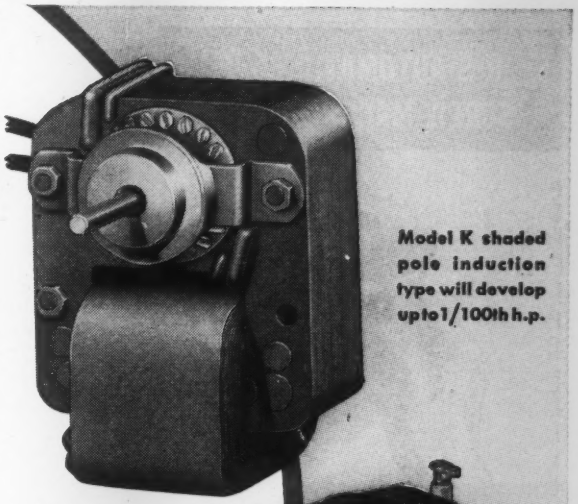
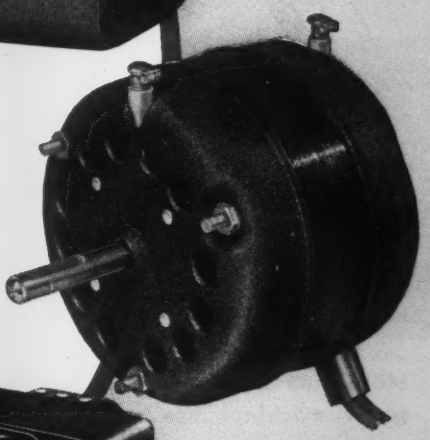
Alliance Motors operate automatic controls, valves, switches, fans and blowers, air circulators, motion displays, phonograph turntables, record changers, air conditioning units, room heaters, automobile heaters, electric fans, magnetic disc tape and wire recorders, radio tuning, automatic television tuning, toys, business machines, hair dryers and numerous other devices.

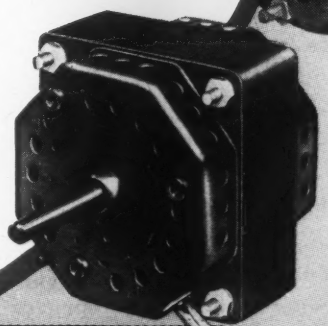
Horse power ratings range all the way from 1/400th up to 1/30th h.p. Alliance Motors are light-weight, compact, and are mass-produced at low cost—made in both shaded pole induction and split-phase resistor type. Designed for particular jobs, some are uni-directional, others are reversible. Alliance makes motors for both continuous and intermittent duty. Wherever designs call for *more motion*—automatic action—remember, there is an Alliance Motor for the job!



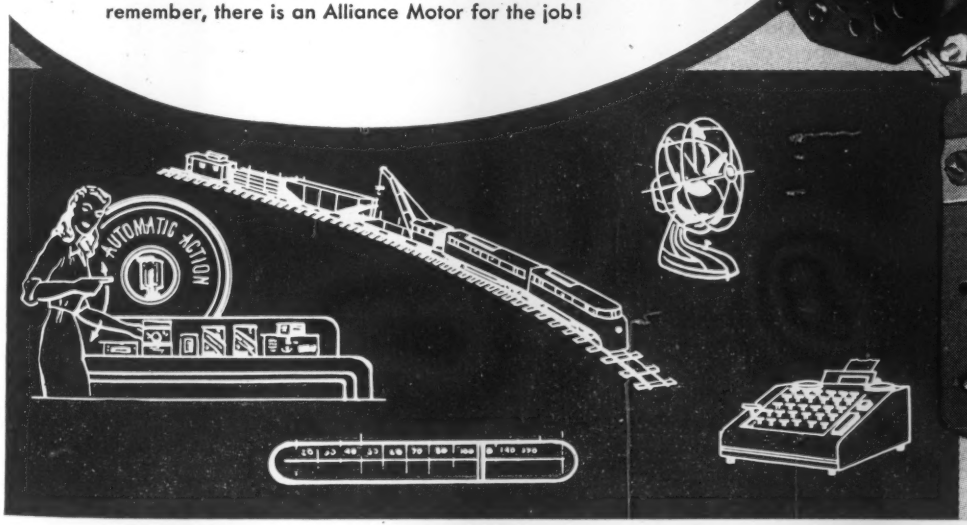
Model K shaded pole induction type will develop up to 1/100th h.p.

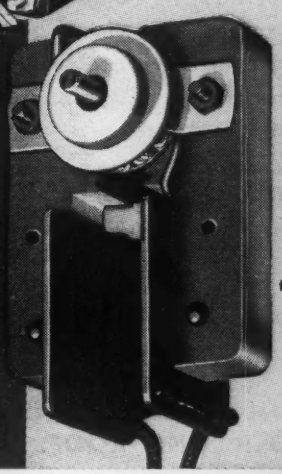


Model A fan motor, 6-pole shaded design. Approximately 1/30th h.p.



Model B—for fans and recorders. Approximately 1/30th h.p. 4-pole shaded pole motor.





Model MS shaded pole induction type motor, full load h.p. .0021

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dles each driven by individual two-speed motor. Speed of work spindle changed by pick-off gears. Thread leads from ½ to 3 in. are possible. Cutter spindle driven through V-belts, spiral-bevel gears and worm gears. Cutter spindle drive furnished with balance wheels on both ends. Separate control for each motor. The James Coulter Machine Co., Bridgeport, Conn.

PORTABLE WELDING HEAD. For continuous arc welding. Electrodes automatically fed from magazine. Is equipped with controls for adjustment of welding current and regulation of arc length. Carriage speed from one to forty inches per minute. Elge Associates, New York.

FORGING BLANK PREFORMER. Preforms, in quantity, uniform forging blanks free of shuts and folds. Air-controlled friction clutch tripped by foot pedal. Upper roll shaft in eccentric bushings permits adjustment of roll shaft spacing. Motor, geared to flywheel, is enclosed in base. The National Machinery Co., Tiffin, O.

WELDER. Three-phase, for mash welding transformer housing tanks. Rated at 200 kva; throat depth, 52 in.; can mash weld two thicknesses of 0.109-in. clean mild steel. Special automatic hydraulically operated locating fixture; four hydraulic cylinders provide high clamping pressure to clamp bars. Sciaky Bros., Inc., Chicago.

LATHE. Medium-size, general-purpose. All-geared headstock with twelve spindle. Spindle head counterbalforged spindle mounted on Timken precision bearings. Gear lubrication by immersion and oil-splash system. Rockford Machine Tool Co., Rockford, Ill.

DRILLING AND TAPPING MACHINES. Electrical pushbutton-controlled hydraulic feed. Single or multiple-spindle. Spindle head counterbalanced by weight. Ways automatically lubricated at each cycle of head. Head automatically sequenced through rapid advance, coarse feed, fine feed, rapid reverse, and stop. Coolant provided by motor-driven centrifugal pump. National Automatic Tool Co., Richmond, Ind.

SPOT WELDERS. Feature 8-step current control permitting 75 per cent secondary voltage adjustment. Electrodes are standard size, water-cooled and easily and quickly renewed. Arc-welded steel casing; spring-loaded foot switch. Electric-Arc, Inc., Newark, N. J.

PRECISION BORING MACHINE. Sealed lubrication system in boring heads; one-piece bed. Unit type hydrau-

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(The modern packing method)
FOR SIMPLICITY • RELIABILITY
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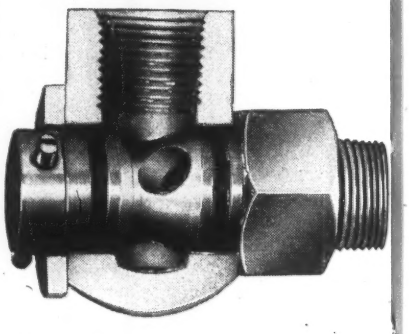

Look at this simple, 4 in 1 swivel union made by MAYSON MANUFACTURING COMPANY of Detroit, Michigan, which may be used as an elbow, union, swivel or banjo fitting. It is made in steel or brass for air, oils, water or hydraulic fluids under vacuum or pressures to 1500 P.S.I.

Note that the use of twin "O" Ring Seals eliminates stuffing boxes and compression packings, compacts the design, reduces weight, reduces costs and enables the union to be broken by hand without the use of tools.

This is another example of how your problem could be solved by using modern "O" Ring Seals.

• Investigate "O" Ring Seals for your packing problems. Consult the "O" Ring pioneers. Send for our "O" Ring Handbook. It's free—no obligation.

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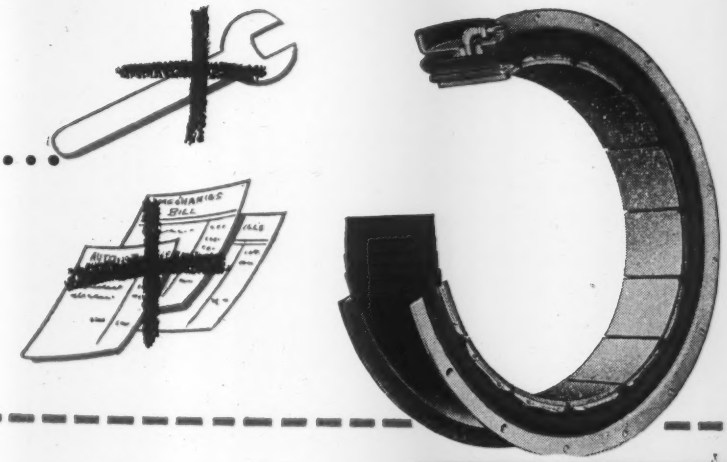


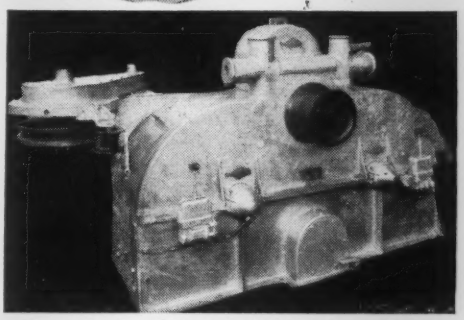
This Clutch Adjusts Itself ...Cuts "Down-Time" Losses

Fawick whips clutch troubles—all of them, and for keeps!

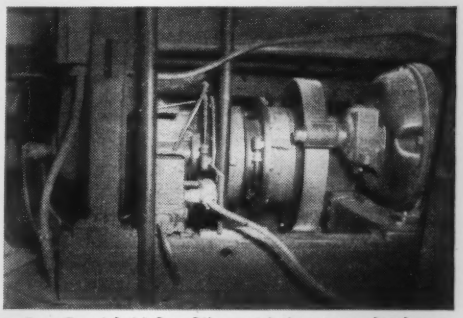
There is only *one* moving part in a Fawick Clutch —the rubber-and-fabric pneumatic tube faced with friction blocks. And this one part naturally stays in perfect adjustment at all times. It automatically compensates for wear of the friction blocks. It puts an end to time-wasting, clutch-adjustment shutdowns.

No wonder users favor Fawick-equipped machines. They do more work at less cost and earn more money. And that's a convincing sales argument that more and more progressive machinery builders are recognizing every day.

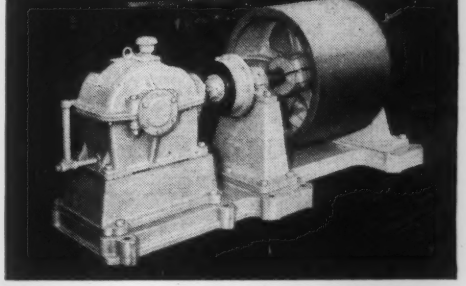
Consult our Engineering Department for specific recommendations of the right types and sizes of Fawick Clutches for your machines.



Three Fawick 24" x 10" clutches on Rowe Machine Works (Seattle) combination winch for fishing craft.



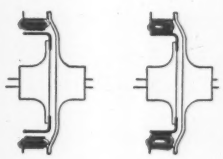
Two Fawick Airflex 8" constricting-type clutches and Fawick Rotorseal on Coe Mfg. Co.'s 120" Clipper for plywood.



Pusey & Jones Corp. dryer drive at Marcalus Mfg. Co., East Paterson, N. J., equipped with Fawick Gap-Mounted Clutch Assembly.

HERE'S HOW IT WORKS

Compressed air expands the rubber-and-fabric gland to engage clutch with any degree of "grip" you want. Deflate gland and clutch disengages.



FAWICK Airflex and AIRING CLUTCH

FAWICK AIRFLEX CO., INC. 9919 Clinton Rd., Cleveland 11, O.

In Canada, Renold-Coventry Ltd., Montreal, Toronto, Vancouver, Quebec • In Britain, Crofts Engineers, Ltd., Bradford, England